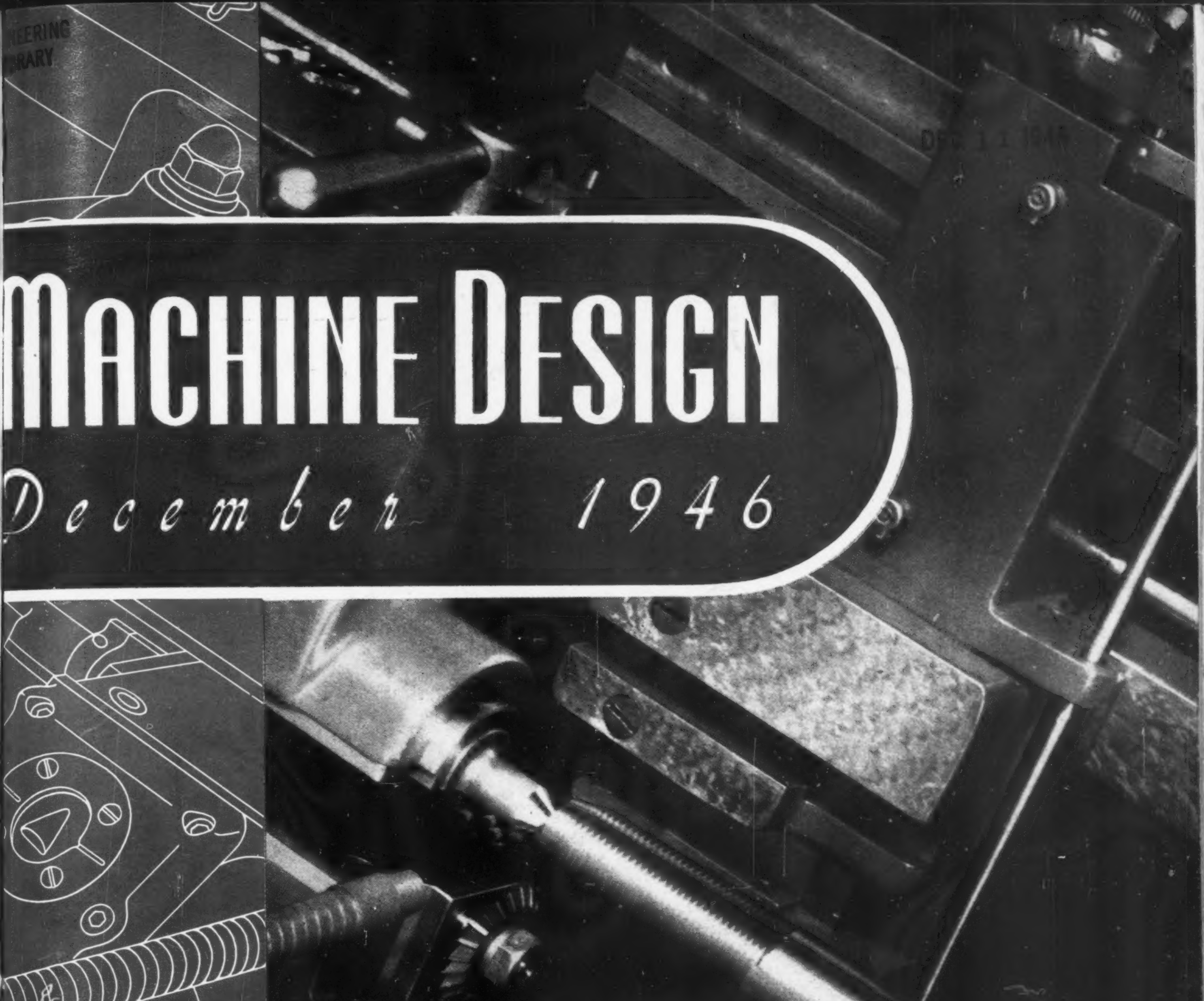
MACHINE DESIGN

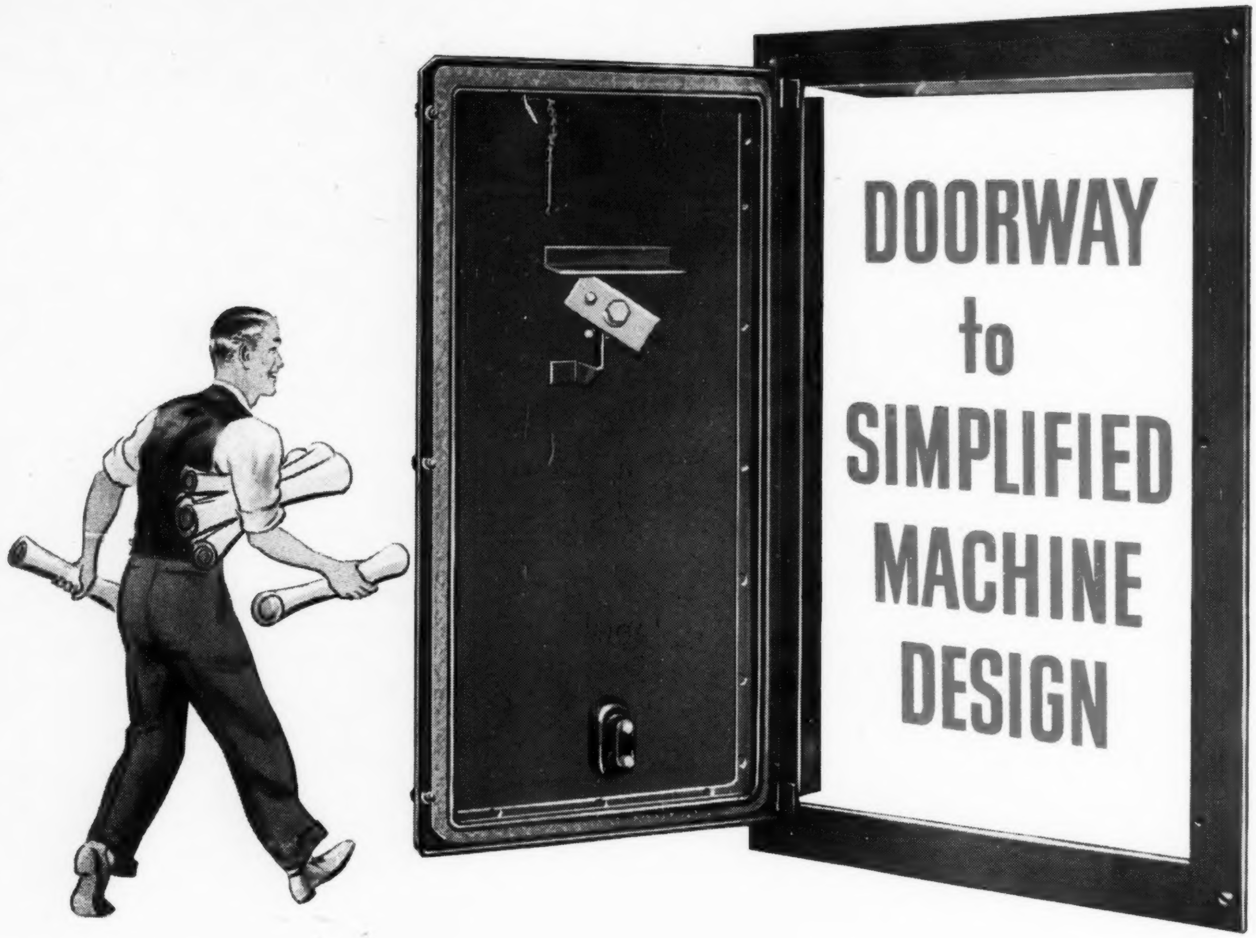
December 1946



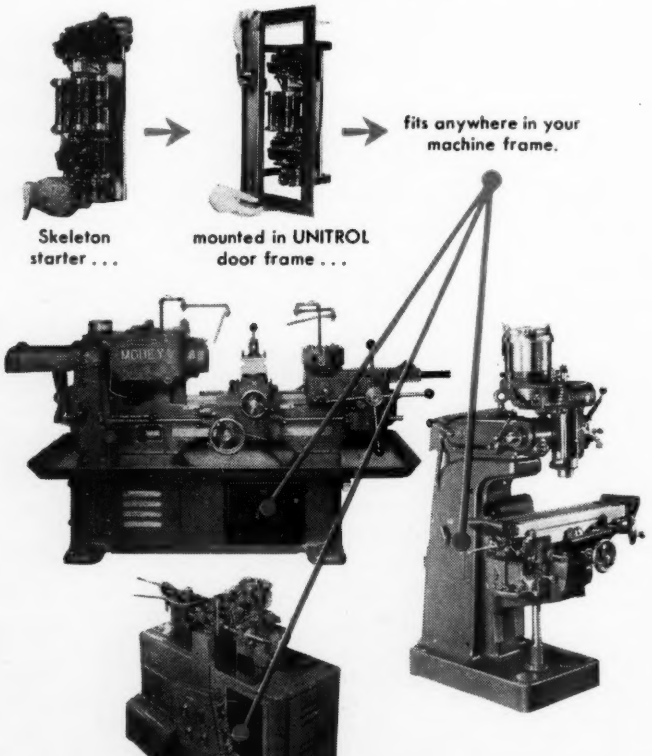
In This Issue:

WHICH CAST STEEL?

FLEXIBLE COUPLINGS IN DESIGN



UNITROL . . . the In-a-door control . . . solves the built-in control problem



UNITROL, the better method of housing starters and other control elements for use in machine design . . . consists of the skeleton motor control mounted in a UNITROL door frame. This assembly possesses extreme flexibility of application. You cast or cut an opening in the frame of your machine and by means of mounting screws, fasten UNITROL into place. It saves assembly, mounting and wiring time. It gives cleaner lines to your machine. It saves material costs . . . no inside mounting base, no outside enclosing case. It makes all control elements easily accessible for use and for servicing. UNITROL is the mark of the modern machine. It means a better machine at a lower cost.

CUTLER-HAMMER, Inc., 1310 St. Paul Avenue, Milwaukee 1, Wis. *Associate:* Canadian Cutler-Hammer, Ltd., Toronto, Ont.

CUTLER-HAMMER
UNITROL
C-H

UNITROL • TRADE MARK REG. U. S. PAT. OFF.

MACHINE DESIGN

THE PROFESSIONAL JOURNAL OF CHIEF ENGINEERS AND DESIGNERS

EDITORIAL STAFF

Laurence E. Jermy, Editor
John W. Greve, Managing Editor

Associate Editors
Colin Carmichael Richard K. Lotz
Roger W. Bolz

Assistant Editors
Harry Raech Jr. H. N. Goga

Frank H. Burgess, Art Editor

New York . . . . B. K. Price, L. E. Browne
Chicago . . . . Erle F. Ross
Pittsburgh . . . . J. C. Sullivan
Detroit . . . . A. H. Allen
Washington . . . . L. M. Lamm
London . . . . Vincent Delport

BUSINESS STAFF

G. O. Hays, Business Manager
Mary L. Callahan, Advertising Service
Chicago . . . . H. H. Dreyer, Manager
New York . . . . R. H. Smith, Manager
E. S. Lawson, Asst. Manager
Cleveland . . . . H. B. Veith, Manager
Los Angeles . . . . F. J. Fuller, Manager

CIRCULATION & RESEARCH

J. W. Zuber, Director
Jack C. Gernhard, Readers Service
R. L. Hartford, Market Research
J. G. Doolittle, Field Representative

MAIN OFFICE

Penton Building, Cleveland 13, Ohio

BRANCH OFFICES

New York 17 . . . . 16 East 43rd St.
Chicago 11 . . . . 520 North Michigan Ave.
Pittsburgh 19 . . . . 2800 Koppers Building
Detroit 2 . . . . 6560 Cass Ave.
Washington 4 . . . 956 National Press Bldg.
Los Angeles 4 130 N. New Hampshire Ave.
London, S.W.1 2 Caxton St., Westminster

Published by The Penton Publishing Co. E. L. Shaner, Pres. and Treas.; G. O. Hays, Vice Pres. and Gen. Mgr.; R. C. Jaenke, Vice Pres.; F. G. Steinebach, Vice Pres. and Secy.; E. L. Werner, Asst. Treas. Published on the seventh of each month.

This Month's Cover: Adjustable sine bar taper attachment on Pratt & Whitney thread miller. A shoe attached to the cross-feed screw contacts the sine bar and produces a transverse movement of the cutter as the carriage is moved longitudinally along the bed.

CONTENTS

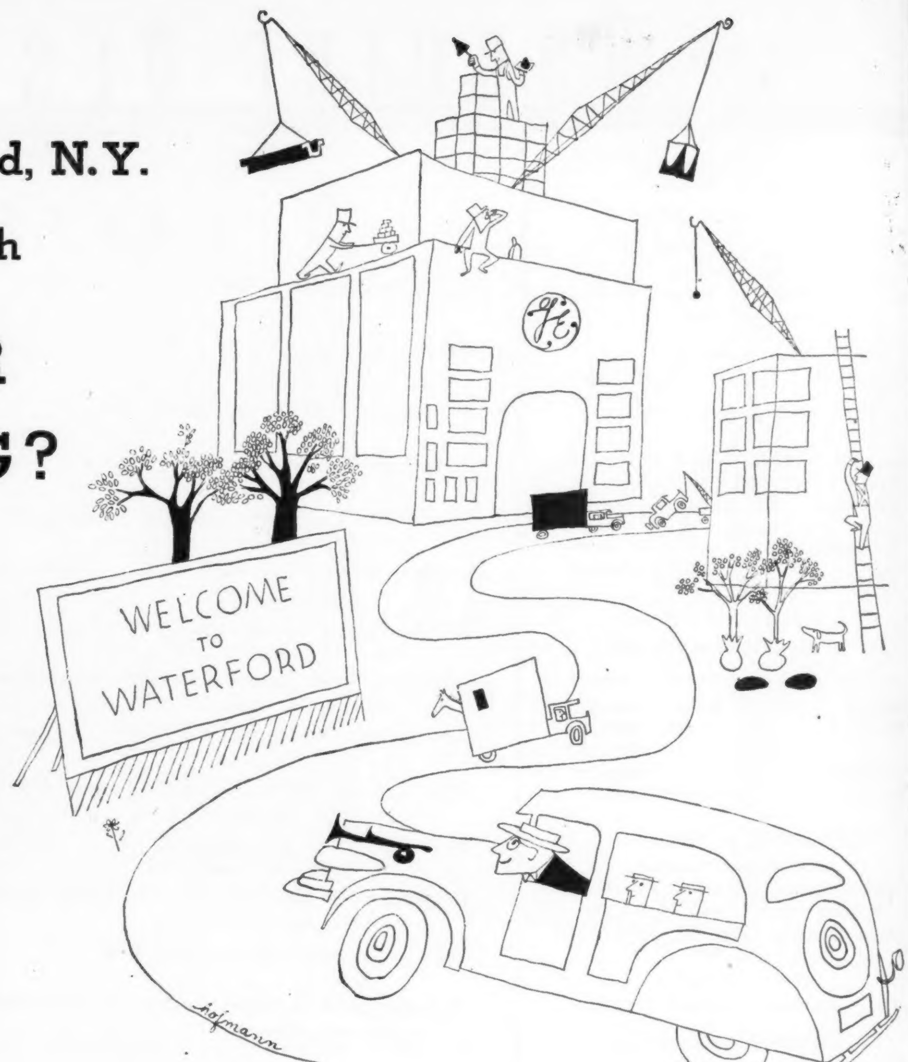
December, 1946 Vol. 18, Number 12

Subscription in United States and possessions, Canada, Cuba, Mexico, Central and South America: One year, $10. Single copies, $1.00. Other Countries One year, $15.

Copyright 1946 by The Penton Publishing Company.

What has Waterford, N.Y. got to do with

BETTER HEARING?



WELL, Waterford, N. Y., is where we're going to do something new about an old hearing aid problem—moisture. On damp, humid days, hearing aids need protection from moisture. For moisture, condensing around the sensitive electron tubes, causes noisy static. At Waterford, where we're building our plant to produce silicone products, we will be able to supply that protection with DRI-FILM, G.E.'s remarkable new water-repellent material.

Already, General Electric engineers have assisted the Sonotone Corporation in working out a DRI-FILM moisture-proofing treatment for hearing aid electron tubes. Radio, television, and public address systems will want its protection, too. But that's only the beginning.

DRI-FILM is fine for glass—textiles—paper—ceramics—plastics—almost any type of material that must shed water quickly and withstand wide ranges of heat and cold.

DRI-FILM isn't the only product our new plant is going to make. Far from it. DRI-FILM has a lot of surprising relatives in the silicone family. There are silicone oils, silicone greases, silicone varnishes, silicone rubber products, and silicone insulating materials. The wonderful thing about them all is the way they can stand up against heat, cold, moisture, and chemicals. Undoubtedly, dozens of new silicone applications will develop as the products become more readily available.

During the war, General Electric's pilot plant turned out silicones in a variety of forms. But the quantities were limited. Soon, with our new plant, we'll be able to produce silicone products by the tank car and by the ton—enough to meet your production needs.

When will that day come? It should be early in 1947. While we're getting ready to make silicones, many manufacturers are getting ready to *use* them. Do you see possible uses for silicones in your production? For more information, consult General Electric. Write to the Chemical Department, General Electric Company, Schenectady 5, N. Y.

YOU'LL BE HEARING A LOT ABOUT

SILICONES

GENERAL ELECTRIC

CD46-S4

Itemized Index

Classified for convenience when studying specific design problems

MACHINE DESIGN is indexed in Industrial Arts Index and Engineering Index Service, both available in libraries generally.

SUPERIOR ABRASION RESISTANCE

Parts made from HYCAR synthetic rubber have 50% greater abrasion resistance than parts made from natural rubber. That means they'll last longer, give more dependable performance in the most severe service, and save maintenance and replacement time.

But that's only one of HYCAR's unusual and valuable properties. Examine the list in the box at the right. Think of these properties in terms of your requirements of rubber parts. Realize that these properties may be had in an almost limitless number of combinations, each designed to meet the specific service conditions of the finished part.

We have developed more than 5000 recipes for HYCAR compounds — each compound engineered to do a certain job. If you're looking for rubber parts that will give long life, dependability, and economical operation, *specify HYCAR.*

Ask your supplier for parts made from HYCAR. Test them in your own applications, difficult or routine. You'll learn for yourself that it's wise to use HYCAR for long-time, dependable performance. For more information, please write Department HO-12 B. F. Goodrich Chemical Company, Rose Building, Cleveland 15, Ohio.

CHECK THESE SUPERIOR FEATURES OF HYCAR

1. *EXTREME OIL RESISTANCE — insuring dimensional stability of parts.*
2. *HIGH TEMPERATURE RESISTANCE—up to 250° F. dry heat; up to 300° F. hot oil.*
3. *ABRASION RESISTANCE—50% greater than natural rubber.*
4. *MINIMUM COLD FLOW—even at elevated temperatures.*
5. *LOW TEMPERATURE FLEXIBILITY—down to —65° F.*
6. *LIGHT WEIGHT—15% to 25% lighter than many other synthetic rubbers.*
7. *AGE RESISTANCE—exceptionally resistant to checking or cracking from oxidation.*
8. *HARDNESS RANGE—compounds can be varied from extremely soft to bone hard.*
9. *NON-ADHERENT TO METAL—compounds will not adhere to metals even after prolonged contact under pressure. (Metal adhesions can be readily obtained when desired.)*

Hycar

Reg. U.S. Pat. Off.

LARGEST PRIVATELY PRODUCED BUTADIENE TYPE

Synthetic Rubber

B. F. Goodrich Chemical Company

A DIVISION OF THE B. F. GOODRICH COMPANY

Magnaflux inspection of Sivyer Castings is just one of the many tests available to Sivyer metallurgists and engineers. Together they mean more exacting control of Sivyer quality: steel castings that measure up to requirements in every way . . . that do a better job, longer.

You can have castings of greater integrity of metal . . . of greater dimensional accuracy . . . of better finishing when you specify Sivyer.

Ask for full details of Sivyer's complete steel casting service.

SIVYER STEEL CASTING COMPANY
MILWAUKEE CHICAGO

Topics

VIBRATIONS for testing may be induced in structures and assemblies by a compact, portable machine known as the Sonntag LA-1 oscillator, developed by Baldwin Locomotive Works. In the unit, centrifugal force is produced by eccentrically supported weights so rotated that all forces add in one direction and cancel each other in all other directions.

UNDER-WATER OPERATION of jeeps for fording rivers has been made possible by extending the intake and exhaust manifolds above the surface and using water-proof distributors and ignition coils, aviation type sparkplugs and an aluminum carburetor housing.

COMPILATION of practical engineering data, prepared by experts at U. S. Army and Navy request to expedite war production, have been made available by SAE special publications department. Manuals cover design of leaf, helical, spiral and volute springs as well as a fundamental comprehensive treatise on evaluation and effects of torsional vibration.

ALUMINUM and its alloys may now be treated to resemble brass and chromium, according to the Colonial Alloys Co. The process is an electrochemical treatment which provides good corrosion and abrasion resistance. High reflective mirror effects are obtained and after-lacquering is not necessary.

STAINLESS STEEL is expected to compete with nylon for hosiery. Fine wire that has been developed for knitting will not run, wear out or absorb perspiration. And it can be wiped clean with a damp cloth.

SHOT PEENING experiments, covered in a 134-page report by R. L. Mattson and J. O. Almen of General Motors, on numerous steel machine parts as well as bar stock test specimens of steel and other metals show the effects of this method of cold working. Primary emphasis was on fatigue durability, but other properties such as static strength, impact resistance, hardness, friction, corrosion resistance, surface roughness, and surface failures also were tested. The report is on sale by the Office of Technical Services, Department of Commerce.

MAGNETIZATION widthwise instead of lengthwise is possible in a new magnetic material composed of silver, manganese and aluminum. The alloy is known as Silmanel.

LABOR-MANAGEMENT relations are being studied by the Committee for Economic Development with the stated aim to "find a pattern of policies for management, labor and government which will avoid interruptions in production while management-labor disputes are being settled; and lead to terms of settlement that serve the general public interest as well as the interests of the immediate parties to disputes."

ELECTRICAL WIRE developed by United States Rubber Co. saves 200 pounds of weight in the Consolidated Vultee B-36. The wire has an aluminum conductor and a fire-resistant insulation consisting of a layer of glass and synthetic rubber applied by dipping. More than 140,000 feet are used in the plane.

ALTHOUGH NOISE is disagreeable and tiring, most types of mental, motor and psychological activity are affected very little except that hearing may be impaired temporarily. This conclusion was drawn by J. P. Egan, Harvard research physicist in reporting extensive experiments conducted at the University.

ENCLOSED AND AUTOMATIC handling of molten magnesium will be of major importance in the casting of magnesium, providing more uniformity of metal and less loss, according to Dow Chemical Co.

MACHINE DESIGN

WHICH CAST STEEL?

By E. J. Wellauer
Supervisor, Research and Metallurgy
The Falk Corp., Milwaukee Wis.

Part I—General Properties and Characteristics

THROUGHOUT the last decade the technology of steel casting manufacture has advanced at a continually accelerated pace. Today castings are available with a full range of properties for sizes ranging from small industrial castings, shown in the lead illustration, to large pressure castings, such as that shown in *Fig.* 1.

Use of steel castings often can reduce manufacturing cost by eliminating or drastically reducing machining, welding, or other processing operations.

FREE OF THE UNFAMILIAR TERMINOLOGY of metallurgy, this down-to-earth series of articles has been prepared to give machine designers, in their own language, practical information on cast steels which will enable them to evaluate and select most competently the types best suited for various parts

Some advantages of steel castings are concisely stated by Bromhead and Piper[1]:

"Alloy steel castings of aircraft quality are lower in cost than steel forgings, since patterns are appreciably less expensive than forging dies, especially when only small quantities of parts are involved, ... furthermore, intricate shapes can be cast much more readily than forged, and there

1. E. B. Bromhead and T. E. Piper (Northrop Aircraft Inc.)—"Steel Castings Replace Forgings," *Iron Age*, Nov. 1, 1945.

are no objectionable directional properties such as occur in forgings. Savings can be effected in machining time since it is possible to cast to close contours approaching the finished dimensons of the part, and such castings can be easily welded to other parts fabricated from wrought steel. . . . . ."

For purposes of preliminary study the natural questions which arise in the designer's mind are: What range of physical properties are available? Can steel castings be heat treated to high tensile strengths? What alloy compositions are obtainable? How can previous experiences with wrought steel be translated into cast-steel designs? In other words, "Which Cast Steel?"

Answers to these questions will be presented from the designer's viewpoint. Data on the properties of cast steels under the extremes of temperature or corrosive conditions will not be presented because of the specialized nature of these applications. Comparisons with wrought steels are made only to enable the designer to use his previous experience with other methods of manufacturing steel parts. No metallurgical concepts are used except when they directly affect the physical properties used by the designer and thereby become a factor in design or specifications.

Data presented on physical properties are largely the results of production tests on acid electric, basic electric, acid open hearth, basic open hearth, and converter melted steels. The steels were melted and heat treated with foundry production equipment. The properties are shown with the "spread" which occurs, thereby reflecting the variations expected from actual production and testing variables.

Properties Evaluated

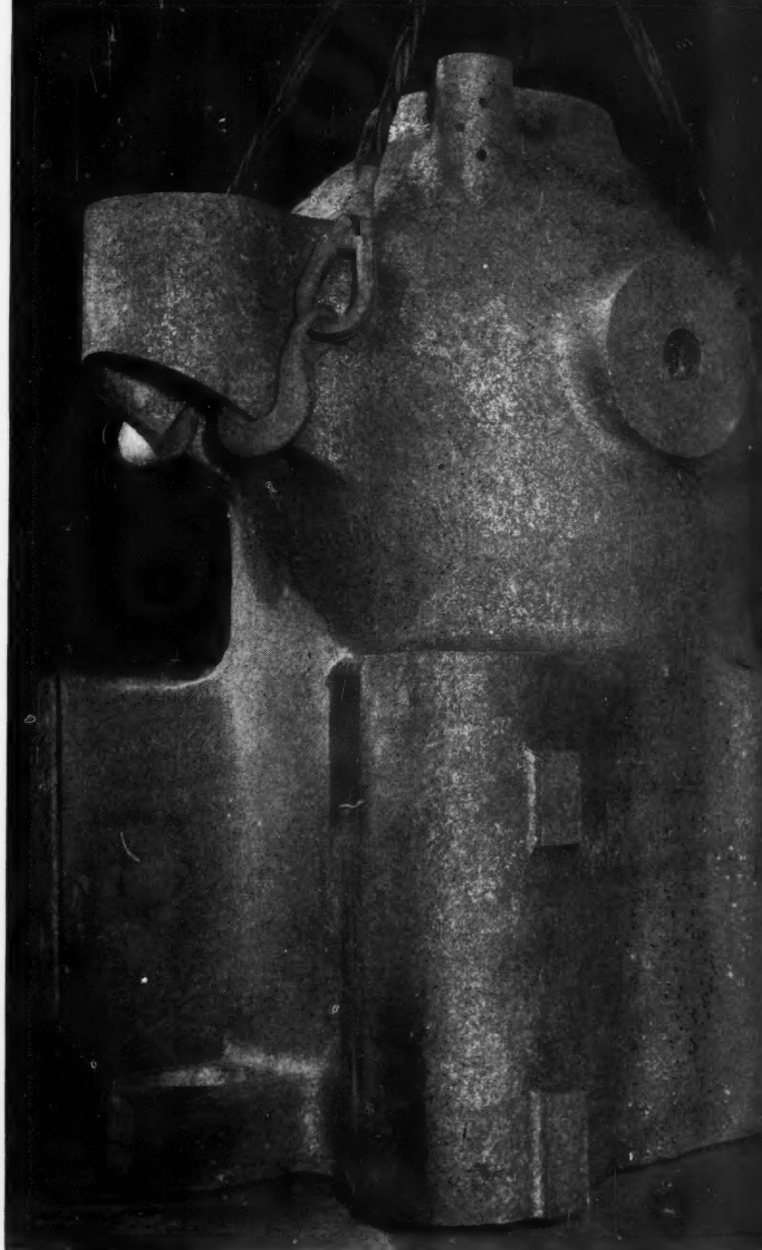
As basic tools the designer uses the tensile test results such as ultimate tensile strength, yield point and the ductility factors; elongation and reduction in area. Also used are approximate data on the endurance limit and sometimes the impact characteristics of steel.

Tensile Strength and Yield Point: During recent years, particularly with the advent of the National Emergency (NE) steels, designers have become conscious of the fact that the alloying contents of steels do not greatly affect the properties, provided the steel responds to a heat treatment so as to obtain a required hardness or tensile strength. Cast steels react accordingly, as is illustrated in *Fig.* 2 which shows the tensile-strength range expected for all varieties of carbon and alloy contents, various heat treatments, grain size variations and melting methods. *Fig.* 3 shows the expected range of physical properties for annealed (slow furnace-cooled) and normalized (air cooled) carbon cast steels. The normalized properties usually will be slightly higher than the annealed properties.

Average tensile strength for cast steels is approximately 500 times the brinell hardness, this factor being identical to that used by many designers for wrought steels. Since the yield point is, for some applications, as important, or more so, than the tensile strength, the designer must know the variations to be expected in cast steels and the means available for specifying the value desired.

Variations of yield point value for a given tensile strength also are shown in *Figs.* 2 and 3. As occurs in wrought steels, a wider spread is found in the yield point than in the tensile strength. The yield point is affected by the response to heat treatment and thereby reflects the size of section and alloy composition.

For quenched steels, the upper curve is about the maximum obtainable and represents complete response to the quenching treatment, secured either by virtue of thin sections of one inch or under for low-alloy steels or thicker sections when alloyed more highly. The average curve for quenched steels represents the yield point to be expected for all grades of steel up to one inch in section for low and medium-alloy steels. It also conforms to the expectations for heavier sections up to two to four inches



with high-alloy contents. The lower limit is the minimum expected for steels which do not respond fully to quenching, usually characterized by straight-carbon steels over one-inch in thickness or insufficiently alloyed steels for sections over three or four inches.

The range given for the annealed or normalized steels is lower than for the quenched and tempered steels. The upper limit usually is secured by virtue of thin (one inch max.) sections or alloys for heavier sections. The low limit is secured either in heavy sections or annealed castings.

As is readily apparent to the designer, the relation of yield point to tensile strength has varying importance depending upon the design stresses imposed on the casting. For example, when endurance limit is important, the design is based on a stress somewhat under 50 per cent of the tensile strength. Under these circum-

Fig. 1—Left—Large parts such as this pressure casting, or extremely small parts (see illustration at beginning of article) are successfully produced as steel castings

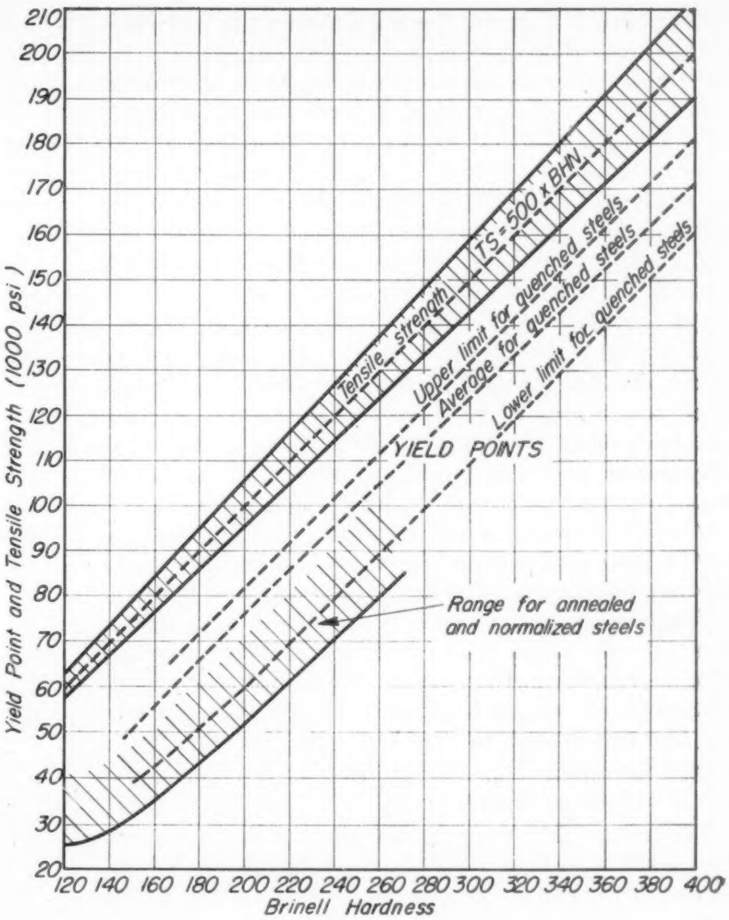


Fig. 2—Right, above—Tensile-strength range of carbon and alloy cast steels of varying grain size, heat treatments and melting methods

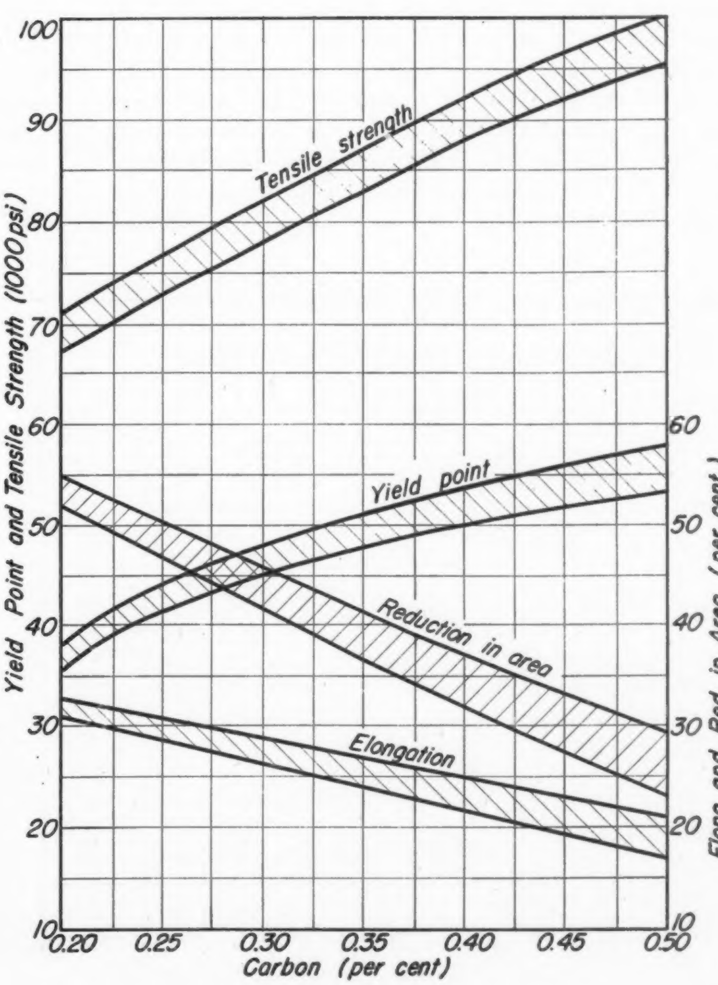


Fig. 3 — Right — Expected ranges of physical properties for annealed and normalized carbon cast steels

stances, tensile strength, because it raises the endurance limit, is more important than the yield strength. In another case, when the allowable working stress is a certain percentage of the yield point, it is obvious that a higher yield point to tensile strength ratio will result in a more efficient utilization of materials. It is pertinent to recognize that with high YP/TS ratios, the more closely the working stress approaches the yield point the greater the likelihood that a complete rupture or fracture of parts will occur in the event of heavy overloads.

For cast steels the yield point increases fairly proportionately with the tensile strength. The highest YP/TS ratio is obtained by a quenching and tempering treatment. Steels which respond most completely to the quenching treatment either by virtue of thin sections or increasing alloy content for increased sections have the highest YP/TS ratio. Annealing (furnace cooled) results in the lowest YP/TS ratio whereas normalizing (air cooled) produces a YP/TS ratio intermediate between annealing and liquid quenching depending upon the size of section and alloying.

Thus the designer can secure the YP/TS ratio he desires. For the higher yield points, consultation is required with the foundry metallurgist to determine the alloying or heat treatment required. Cognizance must be given to the fact that special alloying and heat treatments other than those specified by ASTM specifications usually result in an increase in cost.

Endurance Limit: In many designs the endurance limit is the controlling stress. This is the fatigue strength of cast steels and is directly proportional to the tensile strength, as with wrought steels. Under laboratory conditions in which fatigue test specimens are carefully prepared and uniformly loaded, the usual ratio of flexure (bending) endurance limit to tensile strength is approximately 50 per cent and for torsion approximately 29 per cent of the tensile strength. Allowable endurance limits used in design for forged steels also can be applied to cast steels. The designer is aware of the great effect on fatigue caused by sharp notches, rough surfaces, internal stresses, etc., and realizes that the fatigue strength of machine elements shows a mortality curve which can be obtained only by testing parts under service loadings.

The wide acceptance of cast-steel gears which, according to the American Gear Manufacturer's Association Standards, are rated with the same endurance limit/tensile strength ratio as forged gears, indicates that the endurance limit for steel castings can be made adequate to the design.

Rigidity: There are many designs in which the materials are limited only by the allowable deflections. Cast steel has the same elastic moduli as forged steels, namely, 30,000,000 psi in tension and 12,000,000 psi in torsion. Of practical significance is the fact that steel castings, being free from the limitations imposed when utilizing only standard constructional elements such as bars, plates, channels, etc., allow a greater freedom in design whereby metal can be placed where it will do the most good toward preventing undesirable deflections. Sometimes this allows the more efficient high-strength steels to be used, resulting in an accumulative reduction in weight or cost.

Ductility: Designers, particularly those not previously acquainted with cast steels, sometimes consider cast steel as being brittle and lacking ductility. This is an erroneous impression.

Ductility of steels usually is measured by the elongation and the reduction in area data secured from a tensile test specimen. Usual values secured from all types of analyses are plotted in *Figs.* 4 and 5. It is evident that satisfactory values are obtained which are equal, if not superior, to the average of the longitudinal and transverse tests on wrought steels.

In actual stress computations, the elongation and reduction of area figures are of minor value to the designer. Ductility factors vary with the tensile strength and heat treatment, and the spread probably bears some approximate relationship to the quality of the steel. These factors, therefore, are of value only when correlated with a mass of service information. For such cases, if other than ASTM values are desired for elongation and reduction in area figures, service performance must be compared between various cast steels.

As indicated in *Figs.* 4 and 5, steels which are quenched and tempered to a given tensile strength have a higher elongation and reduction in area than steels which are annealed. Normalized steels have ductility values intermediate between the quenched and annealed steels. The designer should specify the elongation and reduction in area factors contained in the appropriate ASTM specifications for cast steel since these have been determined by both producer and user as adequate.

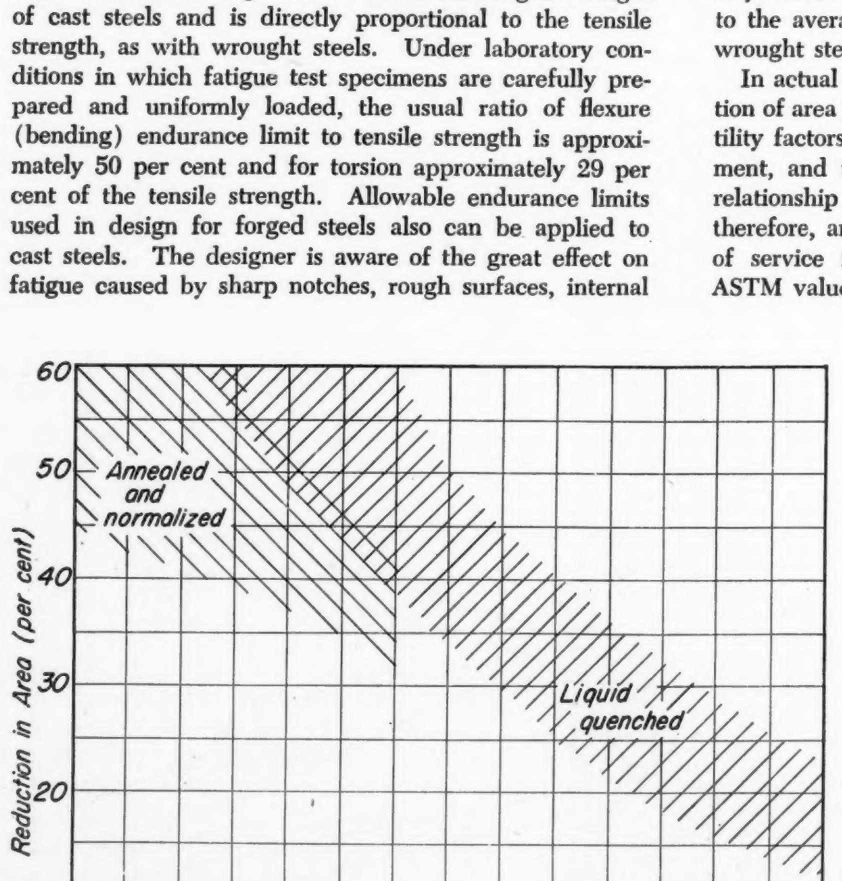


Fig. 4—Reduction in area correlated with tensile strength for all analyses of cast steels in liquid quenched and annealed or normalized conditions

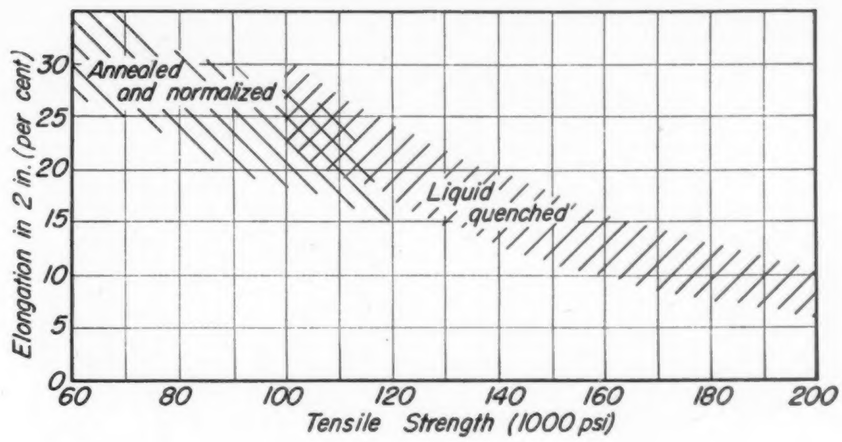


Fig. 5—Per cent elongation correlated with tensile strength for all analyses of cast steels in liquid quenched and annealed or normalized conditions

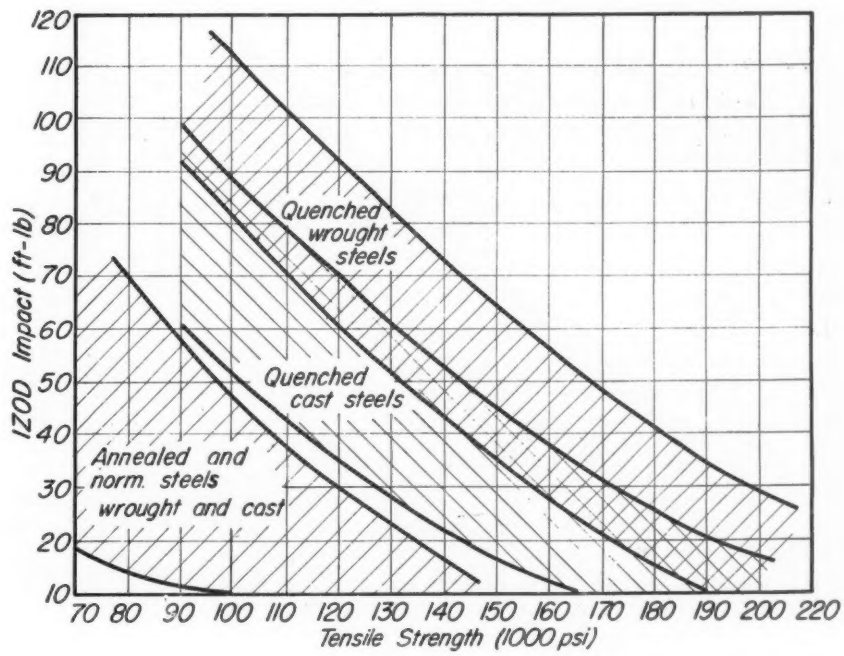


Fig. 6—Comparison of Izod impact strengths of cast and wrought steels in the quenching, and annealing or normalized conditions

Impact Strength: The impact strength of steels as measured by the Charpy or Izod tests have not been particularly useful in any design work because of the inability to correlate technically the test results with any calculated stresses, load velocity or notch effect. As with the elognation and reduction in area factors of the tensile test, impact tests are of value only when specifications are based upon sufficient field service experiences. Cast steel has the valuable property of having uniform impact resistance in all directions in contrast to rolled or forged steels which show marked differences between the longitudinal and transverse directions.

According to available data, the Izod impact strength of cast steels compared to the longitudinal impact strength of wrought steel is as illustrated in *Fig.* 6. Since the transverse impact strength of wrought steels is 30 to 75 per cent of the longitudinal values, depending upon the degree of rolling, drawing, or forging, it is evident that the impact strength of quenched cast steels is equal to or greater than the average of the longitudinal and transverse values of wrought steels.

For annealed or normalized steels of the carbon or low-alloy types, there is no substantial practical difference between the impact strength of quality cast or wrought steels. As a rule, for both cast and wrought steels, the best impact resistance is obtained by liquid quenching with the highest impact resistance being obtained with the steels which respond most fully to heat treatment. This again indicates that alloy steels are useful when the size of section increases because the alloys will provide deeper penetration and better response to a given treatment.

Impact tests seldom are included in cast steel specifications. When used, the values must be based upon sufficient evidence of necessity, since it is pertinent to recognize that the addition of alloys or special treatments required to secure maximum impact resistance increases the cost of a steel casting.

Conclusions: From the data provided, it is evident that the following information is available to the designer to act as a guide for the selection of properties and allowable stresses for cast steels:

1. Cast steels are available in a full range of tensile strengths.
2. The tensile strength has a consistent relation to the brinell hardness similar to wrought steels.
3. The ratio of yield point to tensile strength depends upon the response to heat treatment, which response is affected by the size of section, alloy content and severity of quench. Annealed and normalized steels have a lower yield point to tensile strength ratio than liquid-quenched steels.
4. Elongation and reduction in area factors from the tensile test indicate good ductility for cast steels.
5. Endurance properties of cast steels are similar to those of forged steels.

(*Concluded on Page* 182)

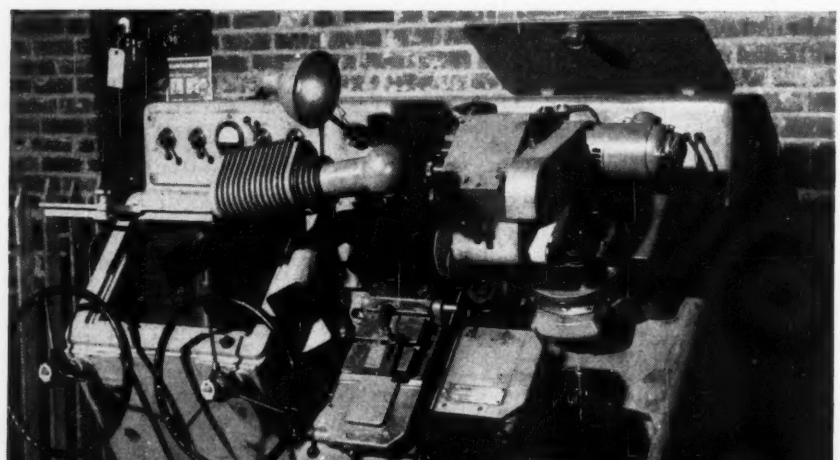
Scanning THE FIELD for Ideas

Projected image of workpiece profile permits grinding to a high degree of accuracy on the projection form-grinding machine shown below. Enlarged either 16 or 40 fold, the image is projected on a screen at the left of the machine. On the screen is drawn a scale profile, enabling the operator to grind to the required shape. With this system it is possible to compare in a simple manner a finished shape with the desired shape without need for subsequent observation by microscope.

In front of the work carriage is mounted a projection lamp which throws an accurate beam of light through an objective lens behind the workpiece, thus producing a sharp image of the work profile on the screen. This screen is composed of two panes of glass, the top one of which is hinged and counterbalanced so that it may be raised for insertion of a matte cellophane screen on which is traced the predetermined form of the work. Behind the screen, mirrors coated with rhodium are positioned in a trough-shaped box to reflect the workpiece image onto the screen.

Objectives for 16 and 40 magnifications, visible behind the grinding wheel, are on a pivot mounting so that either may be swung into position. A green protective filter is employed to prevent abrasive grains from damaging the sensitive lenses.

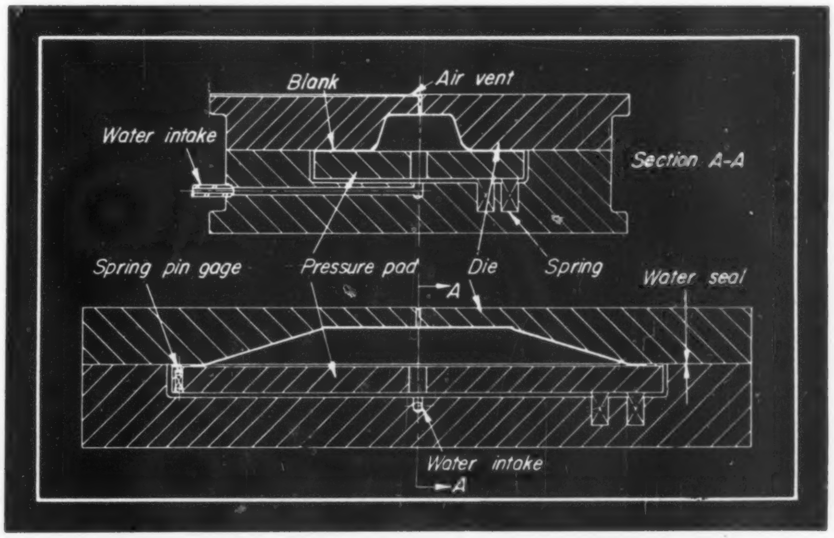
This machine, evacuated from Germany by the Office of Technical Services, Department of Commerce, may also be used for photographing a ground profile on its pattern. For this purpose the pattern is coated with a sensitized material. In addition to producing surface ground forms, templates, etc., the machine is capable of radial and axial cylindrical grinding through the use of suitable attachments. In the latter method the pattern is traced in sectors.



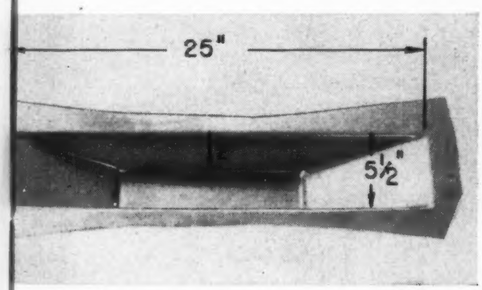
Fluid punch, instead of the conventional mechanical punch employed in drawing and embossing sheet metal, allows forming of many shapes in one operation. With this method several operations and their subsequent annealings and picklings are obviated. Applying a uniform pressure over the entire inside surface of the stamping, the fluid punch is particularly adapted to drawing tapered and conical shapes like that in the photograph at top of next page. This cone was drawn in one

operation from 0.30-inch 18-8 stainless steel. Mechanical means would require at least three operations to prevent fracture at the small point.

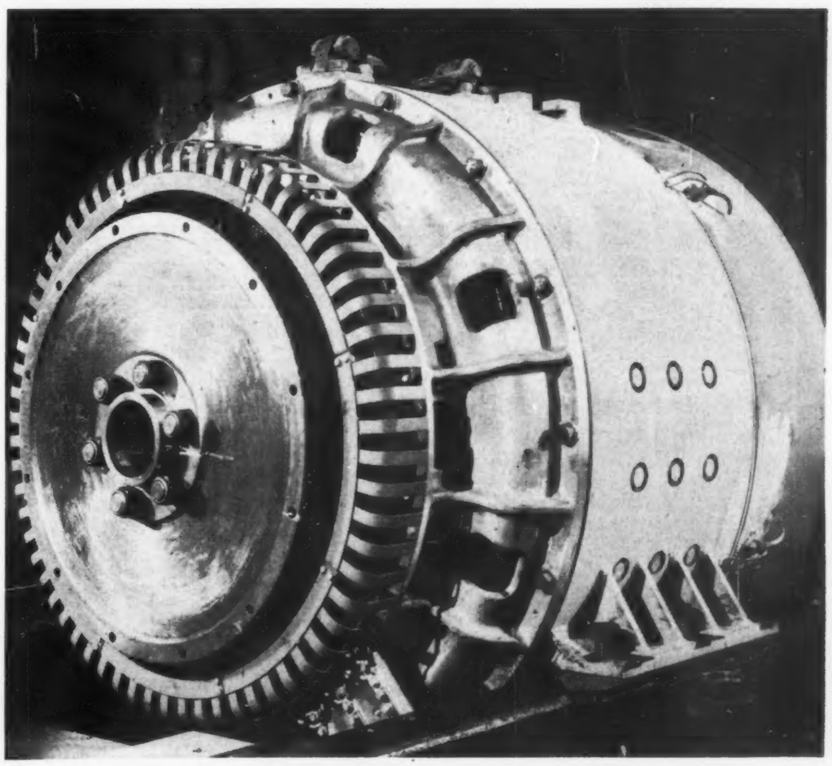
The fluid principle, developed by S. B. Whistler & Sons Inc., is illustrated in the cross-sectional view of a die set shown at right. The part produced from this set is shown below. Referring to the sectional view of the die set, the lower half is a water container and holder for the pressure pad. This pad is actuated by springs set to such a pressure as to allow the blank to move and draw without wrinkling. Spring pin gages serve to locate the blank.



During the forming operation the lower half is brought into contact with the die surface so as to form a water-tight seal. Then water at high pressure is introduced to the underside of the blank surface, drawing the metal into the die until full



shape is obtained. Materials up to 3/16-inch steel have been drawn by this method, producing stampings by surface stretching the metal without moving or disturbing the outer portion of the sheet.

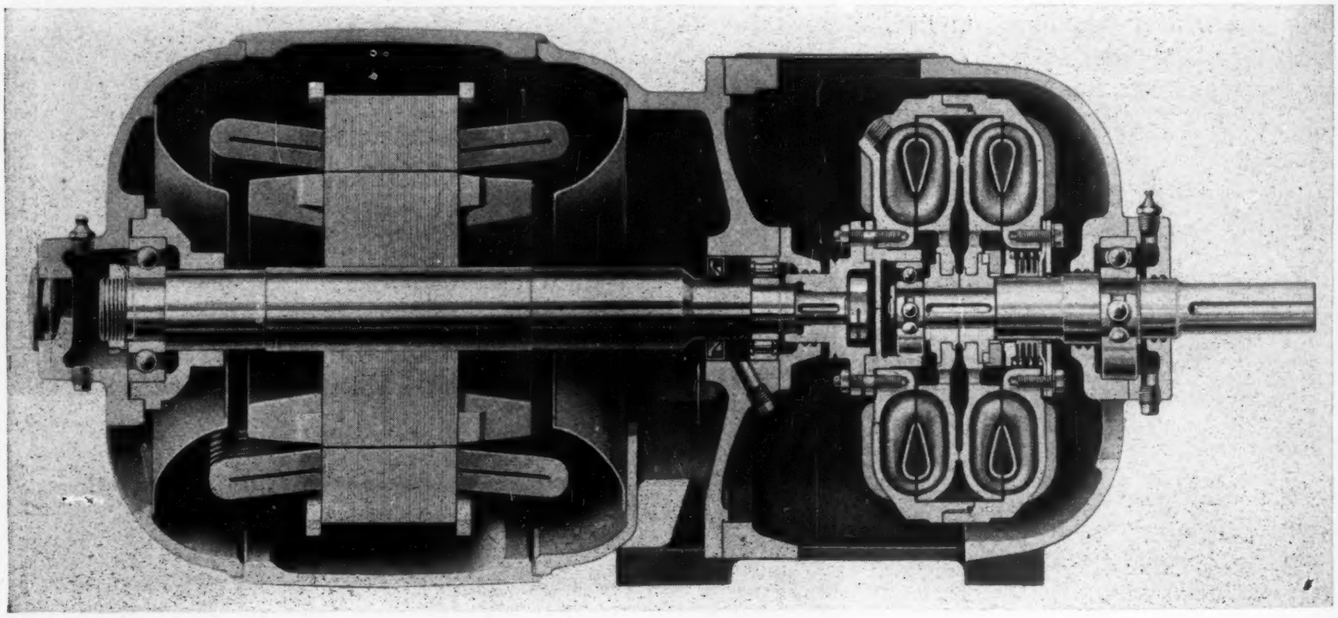


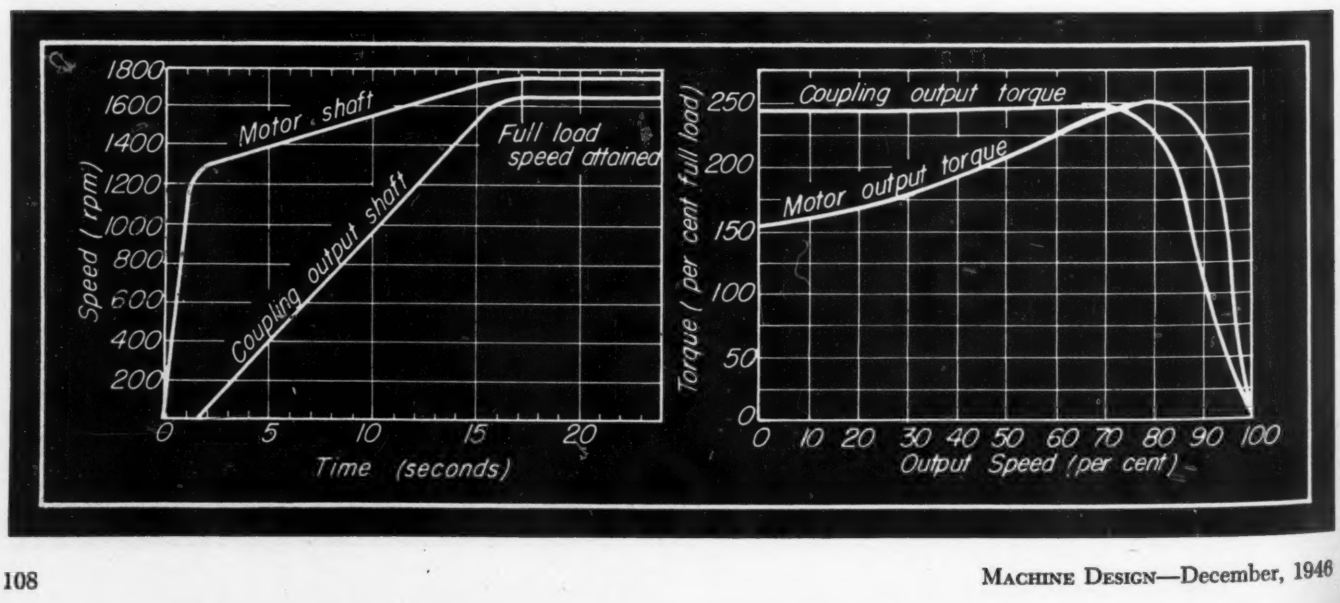
Combination generator shown at right produces both alternating and direct current. Designed by Electro-Motive Division of General Motors the unit has two sets of windings, each delivering current at opposite ends of the generator. The generator, developed for diesel-electric locomotives, produces suffi-

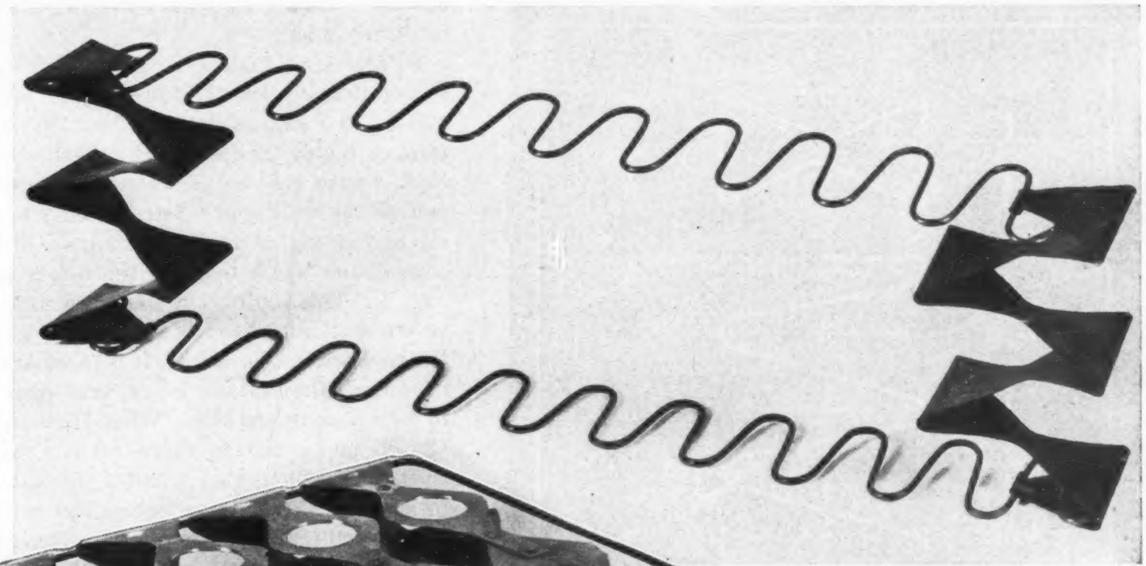
cient alternating current to operate accessories and auxiliaries and still delivers its rated 1500 horsepower in direct current for train propulsion. Because each accessory will be driven by separate alternating-current motors it is possible to group and locate equipment in the most advantageous places. There will be no belts or extension shafts in the locomotive.

Hydraulic coupling mounted integrally on a motor as shown in cross-sectional view below makes a package power unit that improves starting characteristics for many types of drives. Developed by Link-Belt Co., the unit is particularly designed for starting under load where inadequate torque or high starting current peaks are met. Regardless of the characteristics or inertia of the driven machine the motor starts at no load because at zero speed the torque transmitting capacity of a fluid coupling is zero. Therefore the motor may accelerate quickly, developing torque in the coupling in the ratio of the square of the speed until sufficient torque up to the maximum running torque of the motor is developed to start the driven load.

In the acceleration curves the speed of the motor shaft and coupling output shaft show that the motor attains approximately 75 per cent full-load speed before the coupling begins to pick up the load. With the motor accelerating rapidly, the starting current drops quickly to normal values. The curves below show comparative output torque for a standard squirrel-cage induction motor. Nearly maximum torque starts the load from zero in the coupling drive, compared to the slower torque build-up of the motor alone.







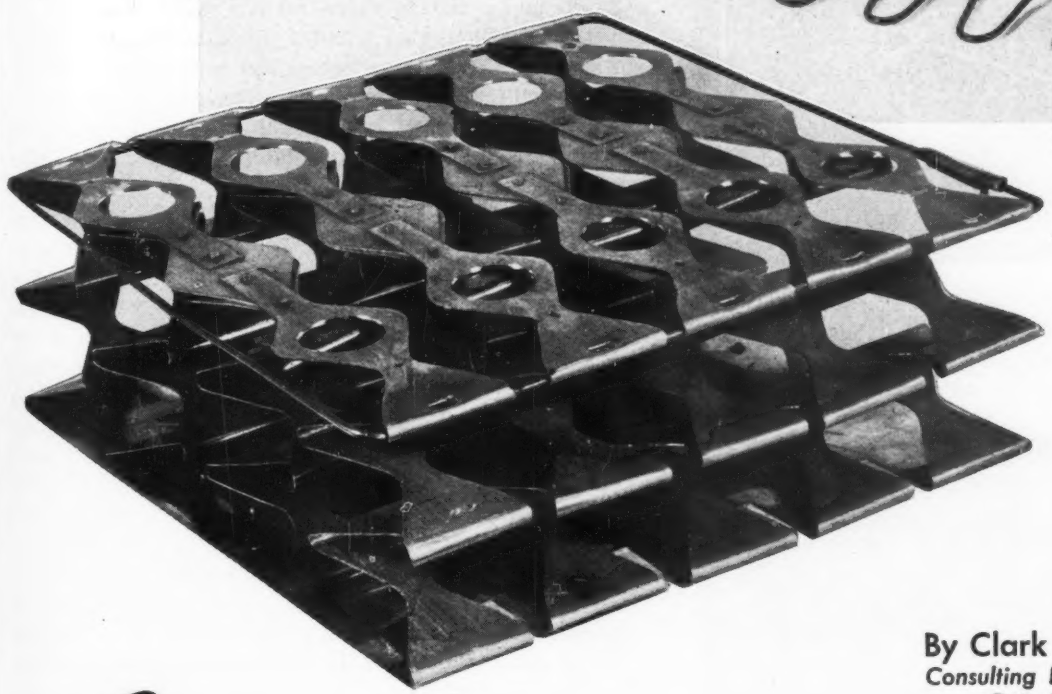


Fig. 1—Above—Two convolute units joined by spans of zig-zag wire

Fig. 2—Left—Aluminum-alloy spring assembly. After die cutting, forming and fabricating the unit was heat treated, making a light aircraft cushion

By Clark A. Tea
Consulting Engineer
Detroit

Convolute Flat Springs

. . . *light-weight, low-cost assemblies have uniform strength characteristics*

ALTHOUGH numerous attempts have been made to design a flat-leaf cushion spring which would not only equal the action of a well designed coil spring but also offer savings in material and manufacturing cost, the results heretofore have not been successful. The most logical explanation is that the increased weight of a uniform-section flat-leaf spring designed to perform and to do the same work as a coil spring, far more than offsets

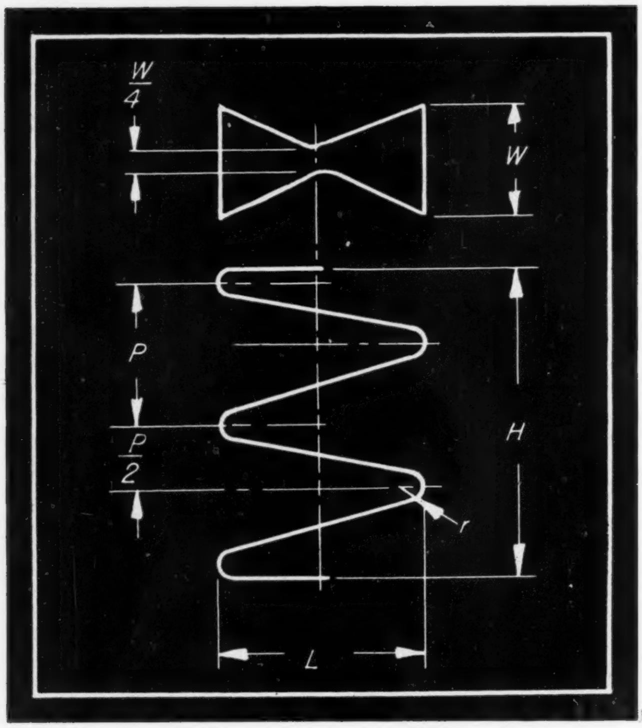
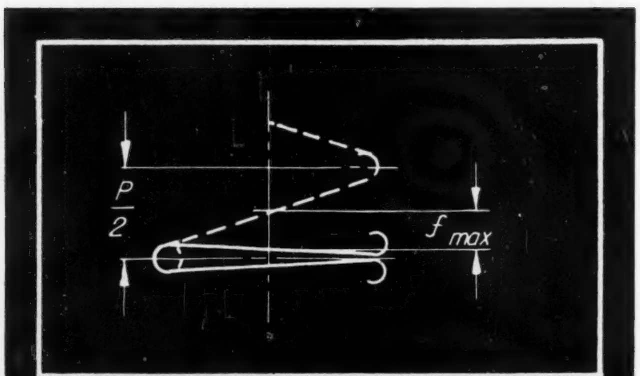


Fig. 3—Above—Convolute spring unit is made up of a series of cantilever springs

Fig. 4—Below—Diagram of spring element, showing maximum deflection obtainable



any advantage gained through labor saving in the manufacturing process.

In searching for greater elastic efficiency in a flat leaf spring design, the uniform-strength beam principle was applied to a strip of flat steel bent into a zig-zag shape to form a highly efficient elastic body called a convolute. Such a strip may be die cut with sinusoidal edges from a coil of flat stock and when formed into a convolute unit, the section varies from a maximum width at the bends to a minimum width between the bends as may be seen in *Fig.* 1. This illustration shows an assembly of two convolute units with spans of zig-zag wire interposed between. Without waste of material, it is possible to die cut (in one operation) duplicate series of these strips integrally joined to a strip along one side. When these integral sections are formed into a zig-zag shape (at one time), they may be riveted or spot welded together, or to additional sections, to produce a spring structure similar to that shown in *Fig.* 2. Die cutting and forming is preferably carried out on annealed or semihard stock which can be brought up to the required yield point in a final heat-treatment, either before or after assembly.

It is important to mention that the bending resistance of the zig-zag wires can be so proportioned in relation to the convolute stiffness as to give any variation of flexibility to and beyond a constant rate of deflection over their entire length. This fact, together with the natural flexibility of the zig-zag wires, makes it possible to use any number of these assemblies in parallel relation to form a spring unit of prescribed cushioning properties, when the assemblies are held together by suitable border wires and interconnecting ties. Satisfactory units have been designed in this manner.

Stress-Deflection Relations

Since the convolute unit is made up of a series of cantilever springs, as shown in *Fig.* 3, each of which carries the full load on the unit, it is essential that each elemental spring be designed as close as possible to a uniform-strength beam for maximum efficiency. For practical reasons, a taper ratio of 4:1 has been selected for all subsequent analyses and calculations. It may be shown that

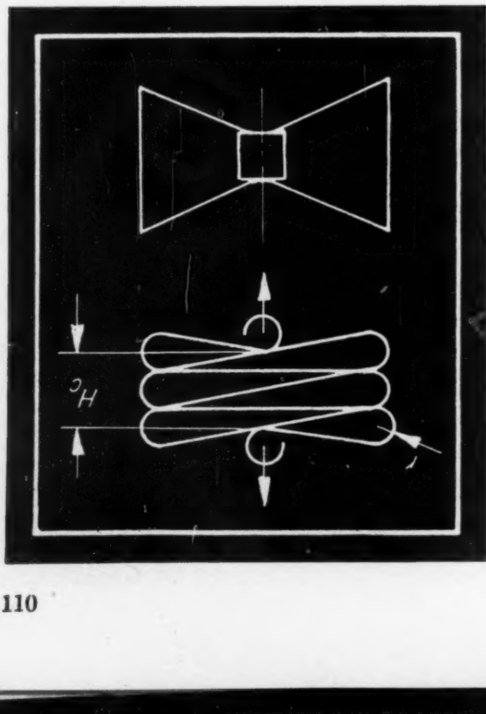


Fig. 5 — Left — Closed height of unit in a tension type spring

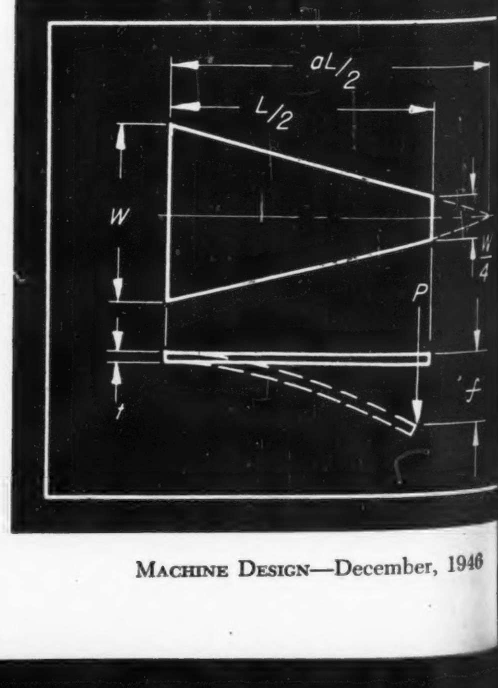


Fig. 6—Right—Diagram of an elemental trapezoidal-profile cantilever type of beam

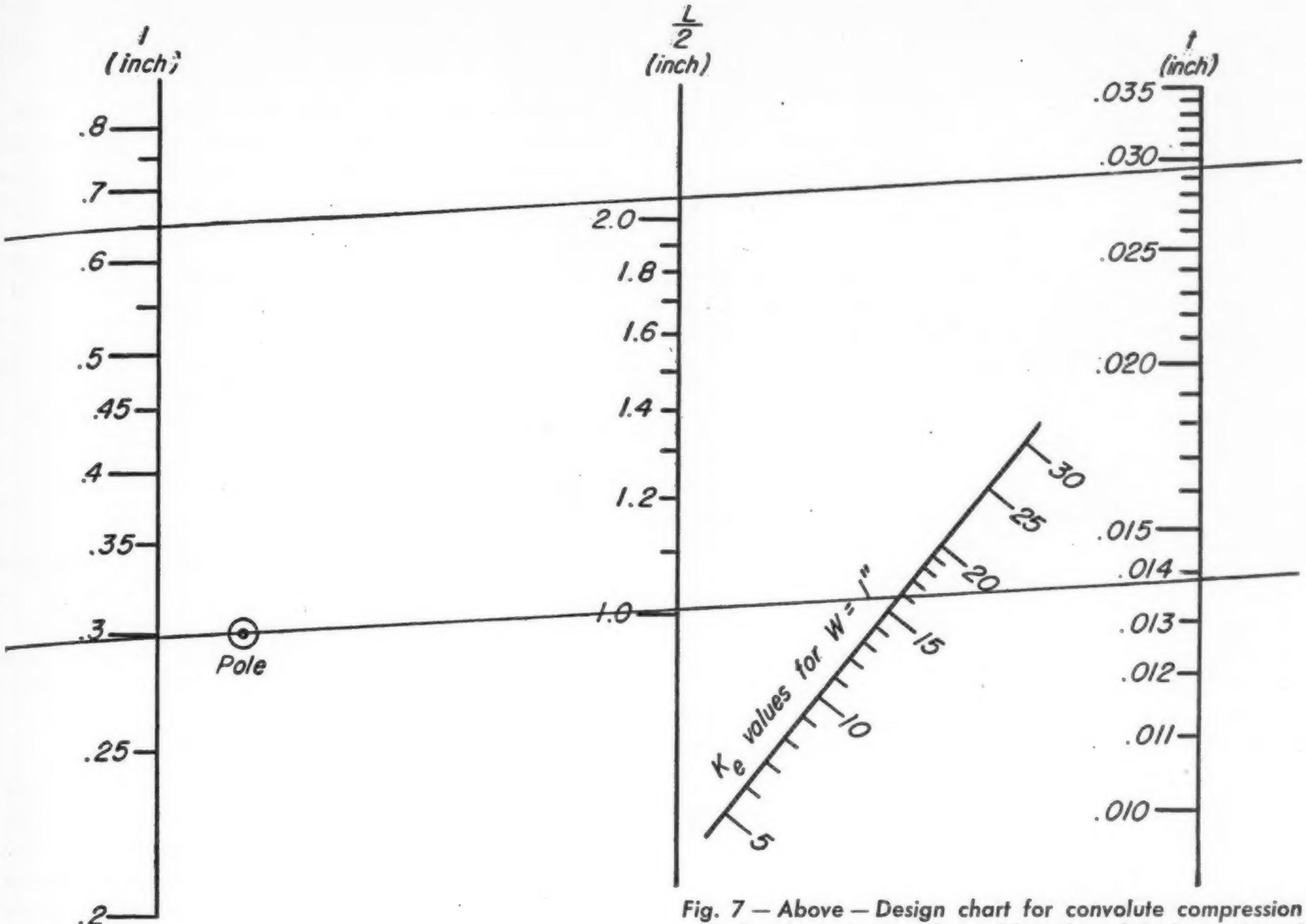


Fig. 7 — Above — Design chart for convolute compression units for determining values of length and thickness, based on 150,000 psi maximum bending stress

this ratio brings the efficiency of the convolute well into line with that of the coil spring*. Also, since the convolute spring can be used to take both compression and tension forces, these will be included in the development of the design formulas which follow:

COMPRESSION: Referring to *Fig.* 3, the pitch of the convolutions is derived as follows:

$$\frac{p}{2}=\frac{H-2r}{n-1}$$

or

$$p=\frac{2(H-2r)}{(n-1)} \quad \ldots\ldots\ldots (1)$$

From *Fig.* 4 the maximum element deflection equals

$$f_{max}=\frac{p}{4}-\frac{r}{2}$$

Therefore by making the necessary substitutions the maximum element deflection in terms of free height, radius of bend, and number of bends becomes

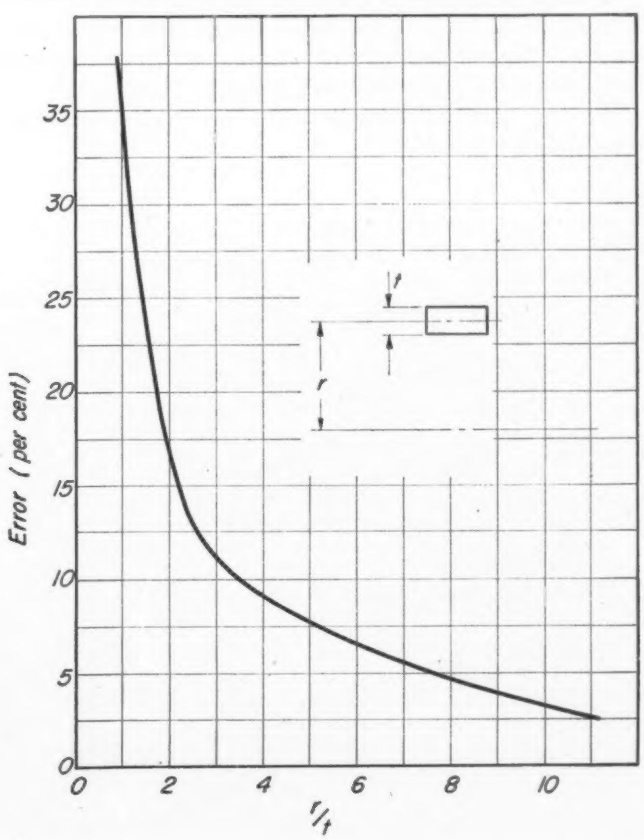
$$f_{max}=\frac{H-r(n+1)}{2(n-1)} \quad \ldots\ldots\ldots (2)$$

The maximum unit deflection is derived from Equation 2 as follows:

$$d_{max}=H-r(n+1) \quad \ldots\ldots\ldots (3)$$

* Comparison of efficiencies of triangular-profile cantilever springs and helical springs is discussed in Chapter XXII of *Mechanical Springs*—A. M. Wahl, Penton Publishing Co.

Fig. 8—Below—Percentage error in normal stress due to assuming linear relationship of stress distribution



Nomenclature

d = Unit deflection	n = Total number of bends
E = Modulus of elasticity	p = Pitch of convolutions
f = Element deflection	P = Unit load
H = Free height	r = Radius of bends
H_c = Closed height	s = Bending stress
K = Unit stiffness	t = Thickness
K_e = Element stiffness	w = Maximum width
L = Length	

assuming that the total deflection is limited by the sum of the greatest number of vertically contacting bends. Combining Equations 2 and 3, the following relation between element and unit deflection is obtained:

$$f=\frac{d}{2(n-1)} \qquad (4)$$

Tension: Referring to *Fig.* 5, the closed height is found to be:

$$H_c=(n-2)r \qquad (5)$$

the thickness of the spring being neglected because of its relative insignificance.

Since in a tension spring all the elements are active, it follows from Equation 4 that the element deflection equals:

$$f=\frac{d}{2n} \qquad (6)$$

In order to design a convolute unit for a given stress and stiffness factor, it is necessary to develop the mathematical relations between element deflection, thickness of material, length of convolutions, and stress. The element stiffness K_e is obtained from the unit stiffness by multiplying the latter by the number of active elements. In the case of the compression spring, it is assumed that the top and bottom elements are inactive because of partial surface constraint. The following formulas are general and apply to both compression and tension springs.

For the elemental beam in *Fig.* 6, the stress is found by the following formula:

$$s=\frac{Mc}{I} \qquad (7)$$

where $M = PL/2$, $c = t/2$, and $I = wt^3/12$. By substituting in and solving the following general expression, where a is the ratio of extended length to spring length as shown in *Fig.* 6,

$$f=\frac{PL^3}{EI_0}\left\{\frac{a}{2}+a(a-1)^2\left[\log_e a-\log_e(a-1)\right]-a(a-1)\right\}$$

$$f=\frac{PL^3}{18.4EI} \qquad (8)$$

Hence

$$\frac{P}{f}=K_e=\frac{18.4EI}{L^3} \qquad (9)$$

By combining Equations 7 and 8, the stress in terms of element deflection becomes

$$s=\frac{4.6Eft}{L^2} \qquad (10)$$

Design Calculations

Equations 9 and 10 are fundamental for all convolute spring design calculations. In order to simplify the designing of compression type units a design chart, *Fig.* 7, has been prepared. This chart is based on 150,000 psi maximum stress, and is considered safe for heat-treated carbon steel. By means of this chart, the thickness and length may be determined quickly for any given maximum deflection and stiffness.

To demonstrate the utility of the design chart, *Fig.* 7, the following example is given:

It is desired to determine the thickness and length of a steel convolute unit for a spring having a 6-inch free height, 2 pounds per inch stiffness factor, 2 inches width, and a safe maximum stress of 150,000 psi.

In a seat cushion spring 5 inches and over in free height, it is usual to assume n equal to 5 and r equal to ⅛-

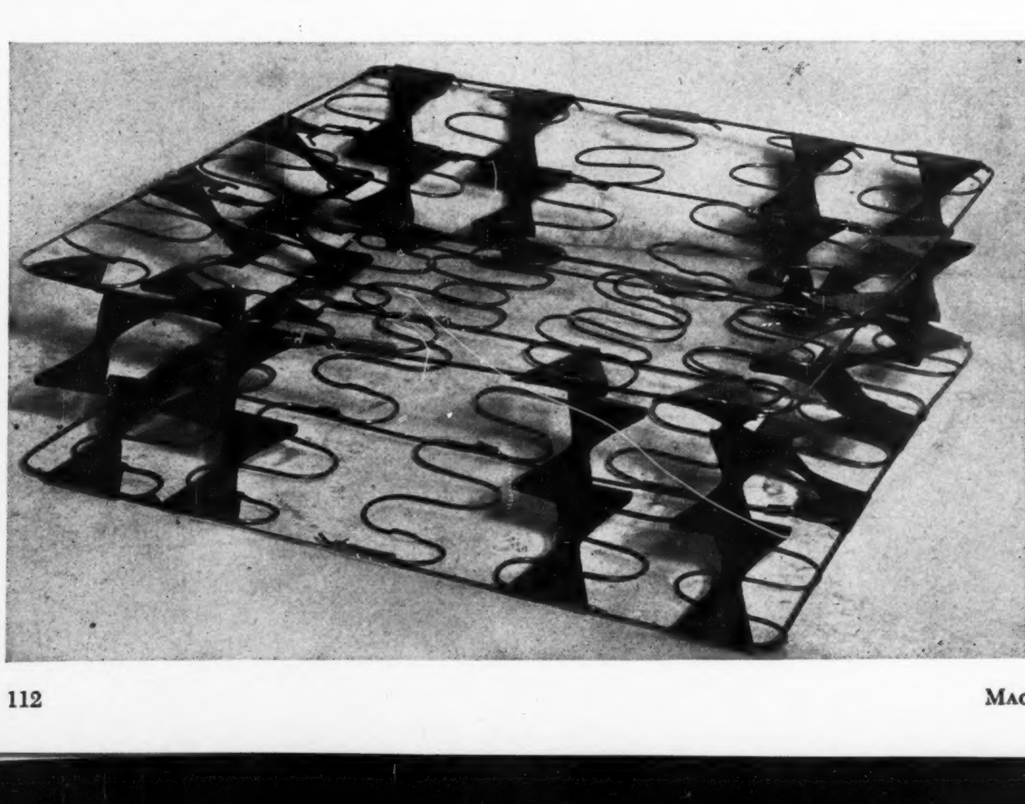
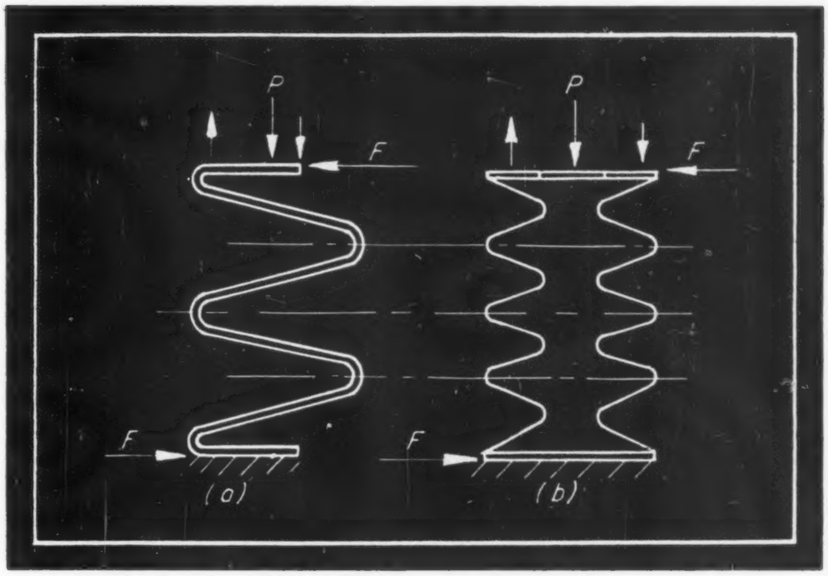


Fig. 9—Balanced design of a convolute zig-zag unit which has inherent stability in all horizontal directions

Fig. 10—Least resistance to a couple is in the plane indicated at (a); maximum resistance is at (b)



inch; therefore from Equation 3, d_{max} = 5¼ inches and, from Equation 4, f = 0.65-inch.

Since there are eight elements in a 5-bend compression unit, and the width is 2 inches, the K_e value equals 16 pounds per inch. Using the chart, a straight line is drawn through the pole and point 8 (= 16/2) on the K_e scale, extending the line on both ends. Then another line is drawn parallel to intersect 0.65-inch on the deflection scale. From this position $L/2$ equals 1.6 inches and t equals 0.018-inch.

In order to find the exact blank length, it is necessary to add to the 3.2-inch working length, the extra stock in the two quarter bends because of the ⅛-inch radius of curvature.

Because of the bends in the convolute unit, the normal stress is increased by a percentage that is dependent upon the ratio of r/t due to assuming linear stress distribution for a straight beam. In the foregoing example, this percentage is small (being roughly 8 per cent) and is not considered a serious enough error to warrant readjustment of the values found. The curve in *Fig.* 8 gives the percentage error in normal stress for r/t values. When the r/t value is 4 or more, the stress error may be neglected for practical purposes.

For other working stress values, such as would be required for tension springs, it is easier to calculate size of the unit from the derived formulas because of the wide range of stress values that are usually encountered.

Practical Applications

While sufficient experimental work has been done to prove the elastic efficiency of the convolute spring and to substantiate design formulas, a considerable amount of actual development work remains to establish details of construction for definite applications. It has been shown the convolutes supply the edge support for the zig-zag wires, and it is believed that such assemblies could be developed to produce light-weight springs with cushioning properties controlled to satisfy individual requirements.

In *Fig.* 9 is shown a convolute zig-zag assembly designed as an inner spring for cushions. In this application the convolutes supply the edge support for the zig-zag wires and are balanced with them to obtain uniform spring action over the entire surface. One of the outstanding advantages of this spring is its natural stability or resistance in all directions to horizontal forces tending to collapse the spring. This feature is accomplished by placing the units at 90 degrees to each other in the two principal horizontal axes, to take advantage of the inherently high resistance of the convolute unit to horizontal forces acting transversely to the direction of the convolutions. *Fig.* 10*a* shows the plane of least resistance to the action of the couple *F-F*, while the resistance in the plane at 90 degrees, shown in *Fig.* 10*b*, is many times greater. This stabilizing resistance, also, is many times that of a coil spring of equal rate, and is not detrimental to comfort because the unit is exceedingly flexible to twisting couples about all horizontal axes.

In the conventional automobile coil spring assembly, diagonal braces must be strategically placed to stabilize the coils fore and aft. These braces are not always to be desired because of their interference with normal coil deflections. Inasmuch as convolutes, when fixed to other supporting members at both ends, offer appreciable edgewise rigidity, there is a possibility of employing a sufficient number along the sides or all around the border of a coil spring assembly to render internal diagonals unnecessary as well as the coils they replace.

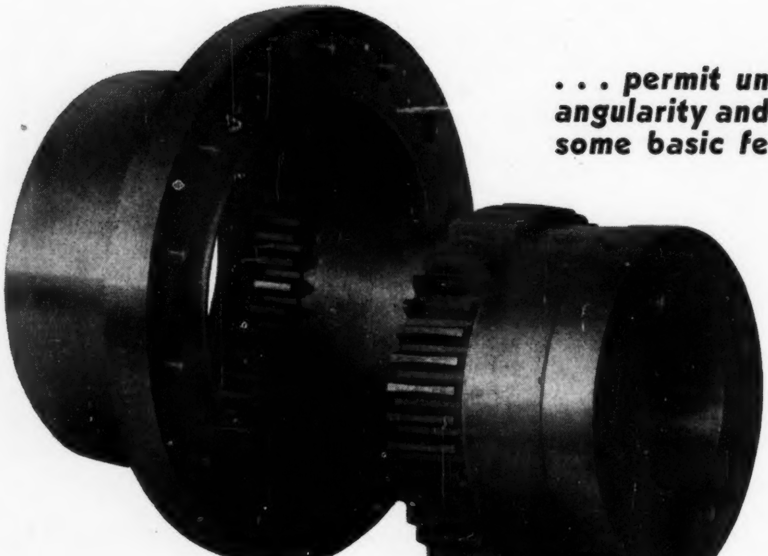
Construction shown in *Fig.* 2 comprises a riveted assembly of four identical aluminum alloy sections which were heat-treated at the comparatively low temperature of 350 F to develop the maximum yield point after completion of all the assembly operations. Simplicity of manufacture and extremely light weight (approximately 2 pounds) are the outstanding features of this construction. It is to be recommended, however, only for a single seat because of the horizontal inelasticity of its top surface. Aluminum alloy sheet is preferable to steel for aircraft applications because of light weight and permissible because there is practically no sustained dynamic cushion spring deflection.

If steel sections were used, they would be spot-welded together in preference to riveting. In such a construction the convolute units, of necessity, are light gage and should be designed as narrow as possible to permit of maximum angular flexibility in all vertical planes. This is not only to attain a maximum degree of comfort but also to limit the torsional stress to a safe degree.

Still another possible convolute spring construction suggests the use of wires to tie the units together in hinged fashion to give more or less independent action, a desirable feature in wide cushion spring assemblies designed for seating more than one person. No doubt there are many other possible applications for the convolute spring where weight saving, low production cost, and comfort are prime objectives.

Gear-tooth Co

. . . permit unlimited axial float plus limited tempor angularity and offset. Their operating characteristics a some basic features of their design are here discuss



By R. L. Benford
Gear Engineering Div.
General Electric Co.
Schenectady, N. Y.

WITH many forms of drive for steam turbines, gas turbines, centrifugal pumps, generators, fans, blowers, compressors, motors and gear sets, transient conditions may cause the connected shafts to move away from the co-axial position. Flexible couplings employed to isolate such temporary angularities, offsets, or vibrations should transmit torque, but not thrust or bending moment. Inasmuch as machines of the foregoing types can be depended upon to operate normally without such disturbances, the flexible coupling duty is short compared to its service as a torque transmitter.

Basically, there are two ways of allowing mechanical flexibility in a shaft coupling: (1) By permitting fairly rigid component parts to roll or slide on each other; or (2) by introducing flexure through the use of thin disks, springs, or springy material. Relative motion between members presents design problems in lubrication and contact loading; flexure of parts necessitates careful design against sagging as well as fatigue and shock loading failure due to stress concentration. Through usage, both types are known as flexible couplings, and many varieties have been made, using one or both of these flexibilities.

GEAR-TOOTH COUPLINGS: The most conventional example of the rigid-component flexible coupling is the gear-tooth type, *Figs*. 1 and 2. Gear-type couplings are acceptable for use in widespread applications because of accumulated successful experience with their performance of special functions, their dependability, and their adaptability to conventional manufacturing procedure. A typical application in which the gear-tooth coupling is used to the virtual exclusion of other types is the geared steam turbine power plant, *Fig*. 3.

A gear-tooth coupling can be designed to allow any reasonable amount of axial float, in the same manner as a simple splined connection. The second flexibility, which permits connected shafts to be misaligned angularly, is obtained by making the splined connection loose-fitting. A third flexibility, which allows connected shafts to be eccentric, is obtained by introducing an intermediate member between two adjacent splined connections. By accommodating offset, a flexible coupling also tends to isolate transverse vibrations in either shaft. A fourth freedom—isolation of torsional vibrations—is gained by making the intermediate member of a prescribed torsional flexibility. The latter feature, however, is found only in special designs of gear-tooth couplings. The standard couplings store negligible amounts of cyclic energy and the driving and driven shafts rotate with identical speeds and accelerations.

Flexible Coupling not a Universal Joint

It should be emphasized early in any discussion of flexible couplings that *a flexible coupling must not be considered a universal joint*. The shafts which the coupling connects should run on the same axis and the alignment should be made as carefully as for rigid couplings. The flexibilities mentioned are expected to be needed during starting, changes in load, and various abnormal conditions, hence a study of transient and emergency needs should be made while analyzing the rated continuous loads.

The standard hub-type flexible coupling is made up of four principal parts, *Fig*. 1. Two similar hubs are used, one on each shaft extension, with spur gear teeth cut into

lings

Fig. 1 — Above — Gear-tooth coupling has four main components—two hubs and a two-part sleeve with a flanged connection. Hubs are shrunk or keyed to the driving and driven shafts

Fig. 2 — Right — Section of hub type gear-tooth coupling with floating female intermediate member

the inboard end. A flanged hollow sleeve with the same number and pitch of mating internal teeth is slipped into mesh with each hub and the two sleeves are then bolted together at their flanges, *Fig*. 4. A rabbetted joint between flanges maintains concentricity of pitch circles at each end.

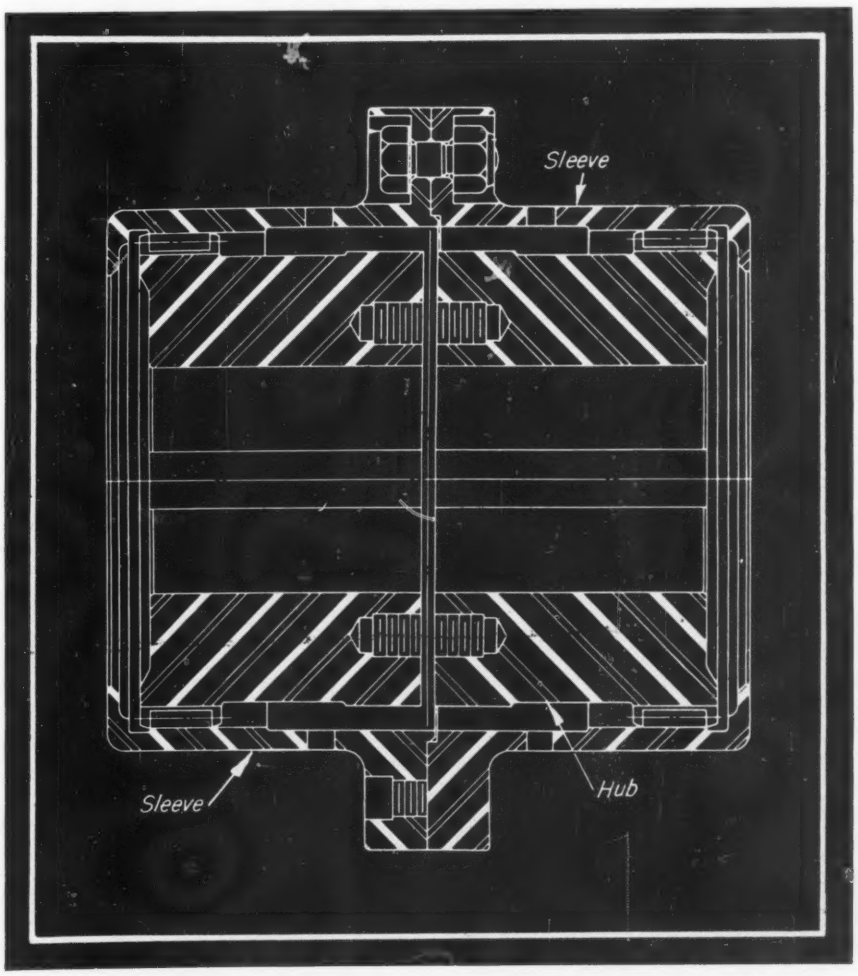
Hubs are fitted on the shafts and usually keyed or splined. When using a taper fit a locknut should be used, since thrust, or strenuous vibration, may cause loosening. The floating female sleeves are centered approximately by one of two means. The first type, recommended for high speeds, is centered by close radial clearances between hub tooth tips and sleeve tooth roots. The second type, good for general use and with grease lubrication, uses metallic or composition rings fastened to the sleeves and bearing loosely around finished parts of the hubs. In either case, the torque transmitted tends to pull the intermediate member concentric with the shafts.

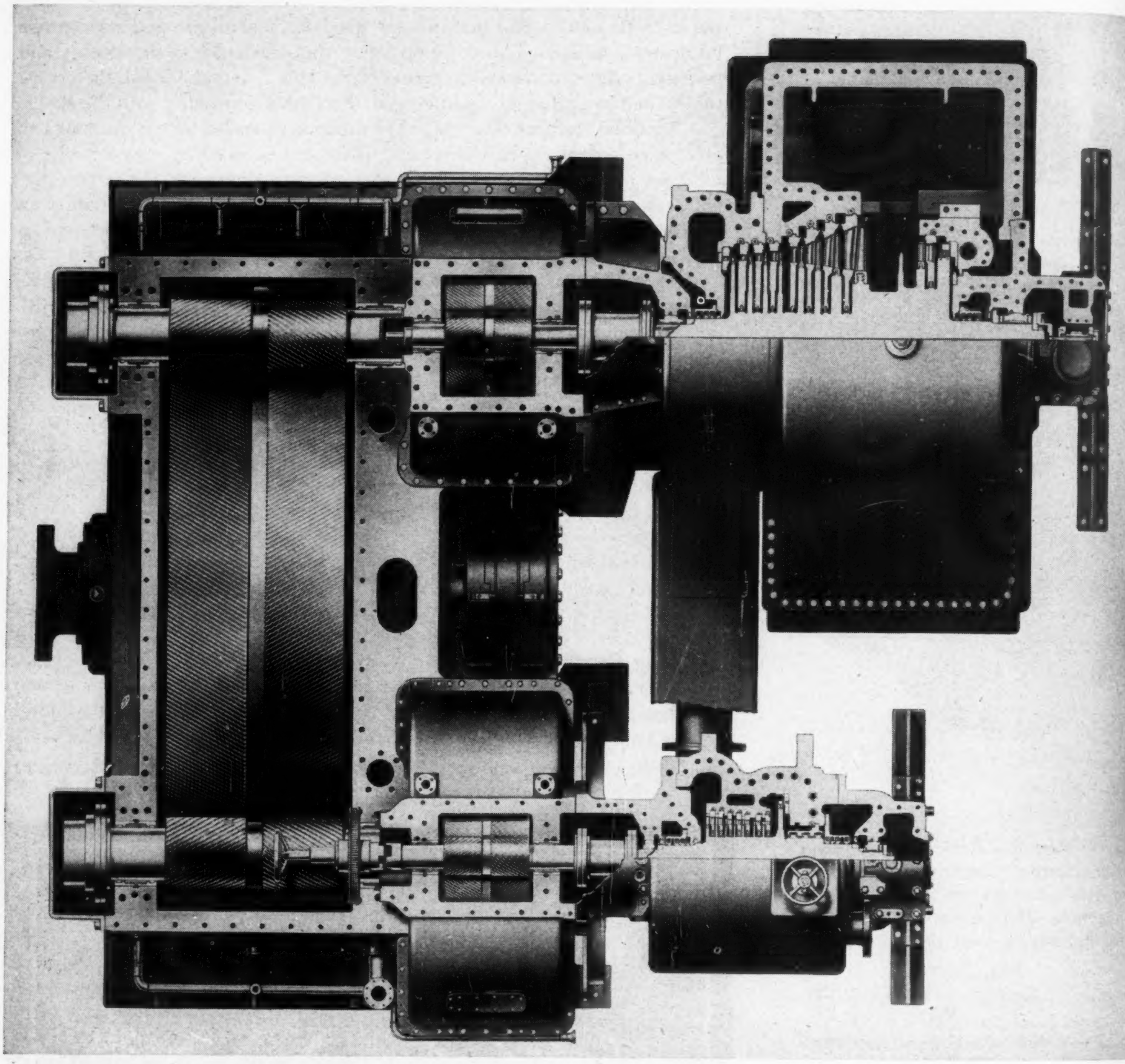
Finished surfaces near the outboard ends of each hub are machined to allow face and sweep checks for angularity and eccentricity, respectively, of adjacent hubs on the shafts to be connected. Alignment of the two machines is checked during installation on their foundations by mounting an indicator on one hub for the sweep check, and by comparing the gaps at 90-degree intervals for the face check.

Gear teeth in the hub are spur teeth with involute profiles. Involute profiles are desirable for several reasons: They are readily machined with accurate contours and spacing; male and female profiles can be matched closely for the full working depth; and the geometrical profile of an involute tooth results in a low bending stress at the root for uniform loading over the working depth, due to the continually increasing pressure angle from the base circle out.

An adaptation of the hub type has a male intermediate member, *Fig*. 5. The female teeth are cut into two sleeves which bolt to flanges on each shaft. The male member usually is a hollow forging with spur teeth hobbed into its raised ends. The male member is called the "distance piece" and the female members the "sleeves". This coupling has some advantages over the hub type. Because there are no press fits, it is easy to assemble and disassemble without disturbing the connected shafts, *Fig*. 6; the intermediate member is light and can move rapidly to compensate for misalignment without inducing serious vibration; the oil flow passages are simple and direct, oil flowing from the collecting lips through feed holes to the tooth section and being flung off the tooth ends; and the coupling can be made lighter than a hub type coupling of equivalent capacity.

Operating Principles: For couplings centered by small clearances





between male tips and female roots, the male tips are rounded in the axial plane to remove the possibility of top corners at either end touching the female root. This machining is usually done before hobbing or shaping the male teeth, and at that time the tooth-stock section is the middle slab of a sphere.

If the male teeth were not yet cut and the female teeth imagined as having been machined off down to their roots, the assembled coupling would consist of a section of a sphere mounted on each shaft, inside of a long cylinder. Shafts can now move in or out, up or down, independently, by a limited amount. The gear teeth are added to transmit torque.

For couplings centered by soft metal or composition rings between hubs and sleeves, the tip clearance of both male and female teeth is large. If these male teeth were not yet cut in their stock and the female teeth imagined as having been bored out, the coupling assembly would be a pair of pistons inside an oversize cylinder. These shafts can also move in and out, or up and down independently of each other, by a limited amount.

Fig. 3—Cross-compound marine turbine connected by gear-tooth flexible couplings to double-reduction gear

If the female sleeve is slipped into mesh with a male hub, and the outer end of the sleeve raised slowly, the rise will be limited by the tooth backlash, because the teeth in mesh in the horizontal plane will jam. The maximum rise is the tooth backlash (circular pitch less sum of tooth thicknesses at pitch line) times the "flexibility." The flexibility of a gear-tooth coupling is the ratio of distance between tooth face centerlines on opposite ends of the intermediate member to the face width at each end. Since the male and female teeth in mesh at each end are of different face widths to allow full contact during endwise movement, the face width of the smaller tooth is referred to in the "flexibility" ratio.

An empirical rule employed for selecting coupling proportions where temporary misalignment must be corrected is to allow one-half thousandth (0.0005-inch) separation of the tooth faces. To estimate the maximum offset permissible with a given coupling, it is only necessary to multiply

the allowable tooth separation by the "flexibility". A common flexibility ratio is 10 to 1, so that offsets up to 0.005-inch can be handled safely for short periods.

Tooth contact in the position described in the foregoing, with the sleeve tipped up until the teeth interfere, varies about the tooth circle. The teeth in the vertical plane are in contact over almost the full working area. In the horizontal plane the teeth engage in line contact, with the leading side of one end of a male tooth and the following side of the opposite end of a male tooth touching the near sides of the adjacent pair of female teeth. By rounding the tooth ends, this contact can be made less harmful by making it an area contact. Between the horizontal and vertical planes, the teeth engage under varying conditions between the two extremes, depending on their angular position. High instantaneous local stresses in compression, due to heavy bearing at one end, cause local yield and the load will distribute itself along each tooth.

If the observation of tooth action in a half coupling is now continued by holding the sleeve in its uppermost position and rotating both members, an exaggerated view of tooth action will be visible. As the teeth which were in the horizontal plane rotate and approach the vertical plane, their faces will be brought together on the driving sides as they near the top, and the tooth axes will diverge. The first motion will cause a gradual increase in tooth contact area with slight axial sliding. Diverging of axes will cause pronounced radial sliding which requires lubrication to protect both surfaces from scuffing or seizing.

If the coupling sleeve is held parallel in an offset position relative to the hub and shaft, another tooth action will take place during rotation. The teeth which start at the bottom and rotate up to the top will slide radially on each other in one direction. At the top there is no sliding, and on rotating further the sliding will reverse its direction until it reaches the bottom. Here the sliding changes direction again. With both angular and offset misalignment, it becomes evident that much sliding takes place between each mating pair of teeth during each revolution. With each complete cycle occurring many times per second, the importance of adequate lubrication is evident. Further, the damaging effect of hard particles contaminating the oil or grease is obvious, as they will be dragged and scraped along the tooth surfaces at high speeds and under high pressures.

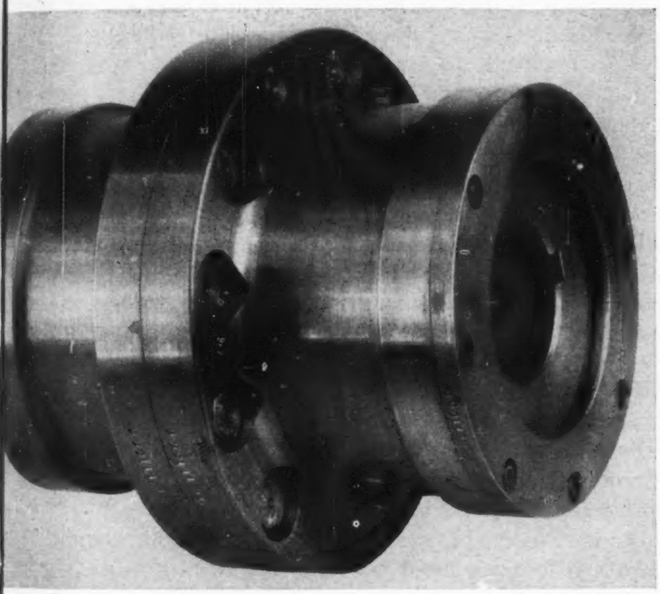


Fig. 4 — Above — Hub-type gear coupling, for 2½-inch shafts, is continuously lubricated by oil directed into the ends from nozzles. The oil drains into a guard through the small holes near the bolting flanges

Factors Affecting Torque Capacity

Torque Capacity Calculation: Flexible coupling size should be based on the expected torque loading, with shocks, vibration, and duty considered. If the connected units operate smoothly and without shock or vibration, and both are carefully aligned, a coupling selected for the largest torque capacity should function as long as the ma-

Fig. 5 — Right — Section of distance-piece type gear-tooth coupling with floating male intermediate member

chine. If one unit vibrates badly or the two are misaligned, the coupling will isolate the vibration as long as its wearing surfaces, the gear teeth, hold up. This condition, however, will bring about involved rubbing and sliding and stress variations at the teeth, and the coupling will fail quickly. The failure may be a fracture of some part or parts, preventing safe transmission of torque, or it may make the coupling inflexible. Ideally, the flexible coupling should continue to perform its job of transmitting torque for as long as the connected units perform, if they operate smoothly, but should be the first to fail if either unit tends to affect the other adversely.

Principal stressed parts in a flexible coupling are the gear teeth, the coupling bolts, the pressed-fit components, and the keys if any. Body stresses in hubs, flanges, and connecting parts are invariably low in a nominally loaded coupling, because of rigidity requirements for manufacture.

Most coupling builders include in their descriptive catalogs a series of standard sizes ("size" is usually the nominal shaft diameter in inches) and the maximum power per rpm. The rating is directly reducible to torque in pound-inches, if multiplied by 63,000 since torque (lb-in.) = 63,000 × hp/rpm. It has been common practice to make the successive torque ratings equal multiples of the next smaller ratings, using the "preferred numbers" system.

Methods of Rating Couplings

There are two common methods of rating couplings by tooth stresses. For general-purpose couplings, a limit is established to the pounds per square inch of tooth face area. The number and size of teeth, as well as the pitch diameters, are selected to give a desired torque capacity for so many psi driving force on the tooth faces.

Another rating is based upon a limiting figure of pounds per linear inch of tooth face, rather than pounds per square inch of tooth "working area." This practice, derived from experience, can be seen to be more realistic when a coupling is called upon frequently to correct misalignment difficulties, since the rubbing and sliding and actual wear do not occur simultaneously over the nominal "working area." Since this is the time interval during a coupling's life when the greatest wear is likely to occur, it is entirely reasonable to limit the line loading to the same unit amount for all sizes.

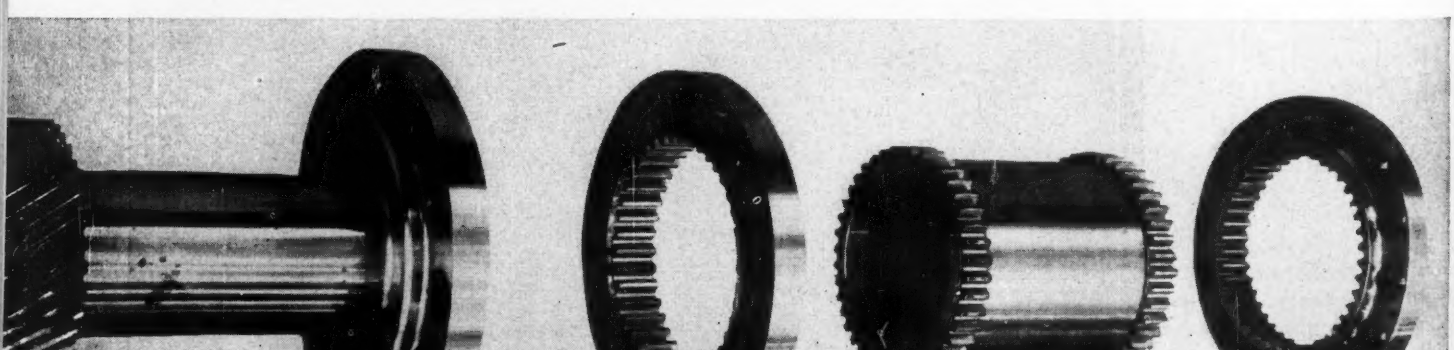
Certain parts of a flexible coupling drive mating parts by static friction. Bolted flanges using clearance between bolts and bolt holes, and press-fitted hubs on shaft extensions are the most prevalent examples. In both of these it is necessary for the designer to have a close estimate of the coefficient of static friction. For machined steel surfaces, in as-machined condition, a value of 0.2 to 0.25 may be used for static friction. This range of values is conservative in many cases, but rarely does it actually measure greater than 0.3 when pressing a hub on or off a shaft.

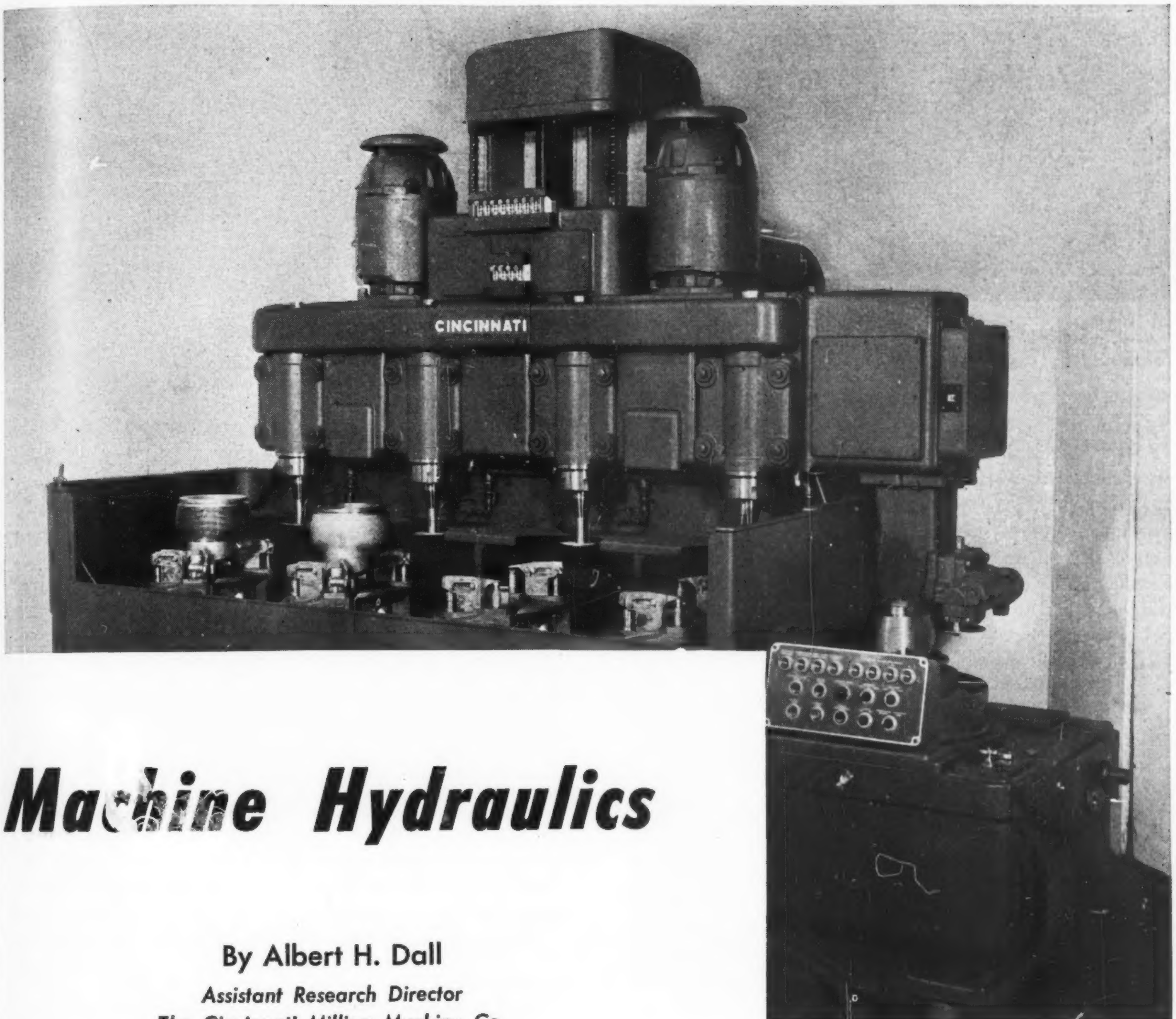
When clearance holes are used with coupling flange bolts, all the driving between members is assumed to be by flange friction. The bolts are intended only to draw the faces tightly together. In calculating the torque capacity two more assumptions, other than the amount of static friction, must be made. These are the equivalent radius at which the tangential frictional force acts, and the tension in the bolts. Tension in the bolts is, of course, almost entirely at the discretion of the man with the wrench, but can usually be safely set at a force which gives a thread-root stress of one-third to one-fourth of the elastic limit. The equivalent radius for the frictional torque will be approximately the bolt circle radius for flanges with unrelieved faces. A surprising result is found when circular grooves are cut into the faces of the flanges. The mean radius of a thin strip near the periphery is the maximum radius available and, as a consequence, a coupling flange is theoretically capable of its greatest friction-torque capacity when all but a thin outer ring of the surface is relieved. This conclusion is based on the fundamental in physics which rules that the frictional force between two surfaces is independent of the contact area.

Another method frequently used for connecting coupling flanges is to insert fitted bolts into line-reamed holes, *Fig. 7*. These bolts are picked of a size and number to carry the full torque in shear. In most applications, only the shear stress in the bolt section at the joint is considered, but where extremely thin flanges are used, the designer should check the crushing stress between bolts and flange hole. The torque capacity of a coupling flange with fitted bolts is calculated directly, without estimate or approximation. Since all bolts are driven into the holes, all bolts will help drive; the mean radius at which the bolts drive is

(*Concluded on Page* 182)

Fig. 6—Component parts of distance-piece type coupling similar to those used in application shown in Fig. 3





Machine Hydraulics

By Albert H. Dall

Assistant Research Director
The Cincinnati Milling Machine Co.

Fig. 40—Machine for milling cooling fins on cylinders utilizes a precision servo valve to trace from a stack of rotating cams by means of a circular disk

Part V—Sensitive Servos and Tracers

UP TO recent years hydraulics has been regarded as a means of moving ponderous masses where the forces were measured in tons. It has been only in the last fifteen years that hydraulics has entered the field of precision machines. The servo valve has in a large measure made possible the use of hydraulics in this field inasmuch as, with such valves, it has been possible to control large forces accurately with tiny signals, *Fig.* 40.

The hydraulic servo idea itself is not new but has been in use for many decades. It is used on ship steering systems and, more recently, has been successfully applied to airplane gyro-pilots. In this latter application, tiny signals from the gyroscope are amplified by the hydraulic servo in order to control the airfoils which in turn control the plane's direction of flight. More recently, experimental models of automobiles and busses have been equipped with hydraulic servo steering mechanisms.

On all machine tools, particularly large ones, it is necessary to move heavy masses with fine precision. In milling machines, for instance, the large forces engendered in the milling process necessitate the use of a large, rigid member to carry the cutter or cutters. At the same time this member must be moved smoothly and accurately if the product of the machine is to be accurate. The hydraulic servo has helped to solve the problem of smoothness and accuracy and at the same time has provided an ease of operation which is little short of phenomenal.

Precision Servo Valve: The precision servo valve, as used in most machine tools, has evolved from the ordinary spool type reversing valve by again applying the principles of the Wheatstone bridge (See Part II—Balanced Circuits). In *Fig.* 41 is shown a simple type of servo valve application wherein the feedback is obtained by making the valve body and slide integral. Thus, when the servo is displaced, fluid flows to the cylinder in one direction or the other and the slide, taking the valve body with it,

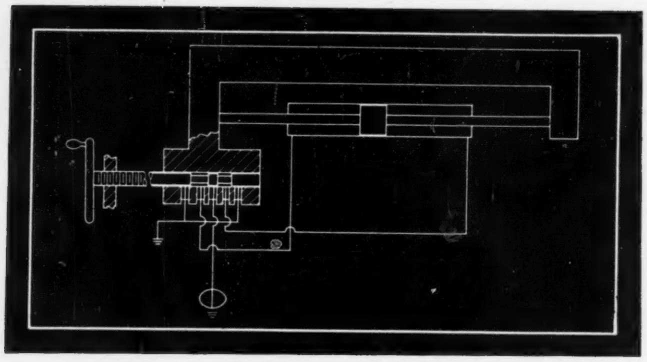


Fig. 41—Simple servo valve arrangement with feedback obtained by making the valve body and slide integral

moves in a direction to close off the active valve ports.

In *Fig.* 42 is shown a valve having all the elements of a reversing valve. However, each port and its corresponding valve shoulder is spaced accurately, each creating a resistance so that by design $R_1 = R_4$ and $R_2 = R_3$. These four resulting resistances form the elements of a hydraulic Wheatstone bridge, as in the lower diagram of *Fig.* 42. Assuming that resistance R_1 is equal to R_4 and R_2 is equal to R_3 at all times, the equation for pressure drop across the junctions becomes

$$P_1-P_2=P_0\left(\frac{R_2-R_1}{R_2+R_1}\right) \qquad (15)$$

or

$$P_1-P_2=P_0\left(\frac{R_3-R_4}{R_3+R_4}\right) \qquad (16)$$

Thus if either R_1 or R_2 approaches infinity in a small movement of the valve, the resistance term approaches plus or minus 1, and the pressure difference from one valve neck to the other approaches pump pressure P_0.

Achieves Smooth Operation

Ports P_1 and P_2 of the valve are connected to the motor which moves a slide as indicated in *Fig.* 41. When sufficient pressure difference is obtained by displacement of the valve stem, the flow condition in the bridge changes, fluid leaving one junction and entering the other. This change in flow conditions has the effect of reducing the pressure difference across the junctions. A further tendency to reduce the pressure difference is caused when the motor movement, through its feedback, moves the valve body in a direction to restore the valve to its mid-position. Thus the initial pressure difference which accelerates the slide is followed by a decline in pressure difference. This is highly desirable for smooth operation.

Servo Valve Characteristics: In *Fig.* 43 are shown some curves made from actual test data on two valves. The middle pair apply to an extremely sensitive servo valve, while the light curves are for a less sensitive valve. Valve position is plotted against the oil volume passed by the four ports at various positions of the valve using 150 psi pressure introduced at the neck ports. The curves indicate that each port of the sensitive valve 1 will go from full closed to full open in approximately 0.003-inch while those of the less sensitive valve 2 require a motion which is four times as great from full open to closed position.

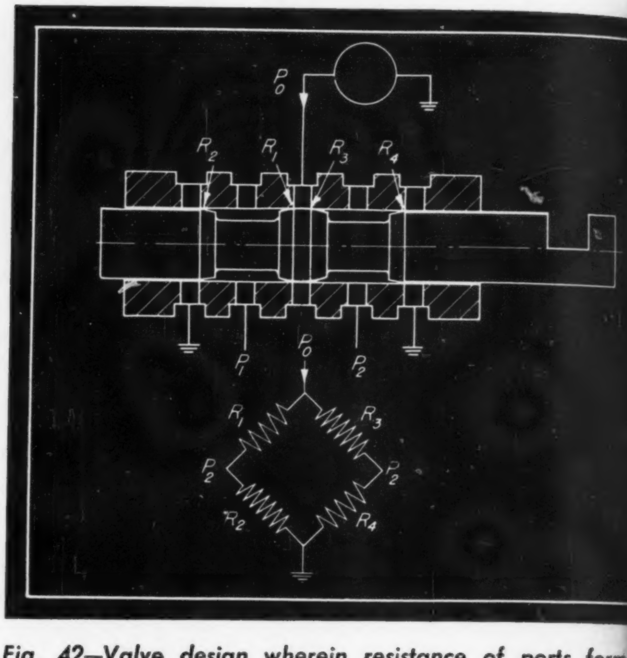


Fig. 42—Valve design wherein resistance of ports form the elements of a hydraulic Wheatstone bridge

A unique method is used to obtain the desired accuracy on valves designed as shown in *Fig.* 43. The valves and bushings are made to ordinary machining tolerances with stock allowances on the shoulders. After selective assembly, hydraulic tests are made on each valve by measuring the flows at the various throttling ports, using constant-pressure input at constant oil temperature. From these data, the amount of stock to be removed from each shoulder is easily determined. After the valve is ground, the hydraulic test is repeated. Usually the valve is found to have exactly the right characteristics after one grinding. The curves in *Fig.* 44 show the valve characteristics in terms of resistance units versus valve movement.

In *Fig.* 45, the pressure difference across the valve necks is plotted versus the valve movement, using Equation 15. The pressure difference is given as a percentage of P_0 which is the term (R_2-R_1/R_2+R_1) times 100. This indicates the extremely high sensitivity which can be obtained in valves of this type. For a movement of only 0.0001-inch (with a pressure input of 500 psi) the pressure difference produced is already 75 psi.

Control of Oscillation: In questioning the desirability of using a servo valve of highest sensitivity at all times it should be pointed out that, unless preventive precautions are provided, the use of servo valves of great sensitivity usually results in oscillation of the slide which is being moved. Because valves of extreme sensitivity close and open completely in an extremely short distance, the action of the valve approaches that of a switch. Thus when the valve is moved slightly, a rush of fluid goes to the motor and the slide is accelerated at a high rate. A very small movement of the slide closes the valve. However, the potential energy stored in the forward column of oil, plus the kinetic energy in the slide, causes a continuation of movement of the slide until the flow is reversed, after which the process is repeated in the opposite direction.

On some applications, however, oscillation of low amplitude and high frequency is desirable, as will be shown

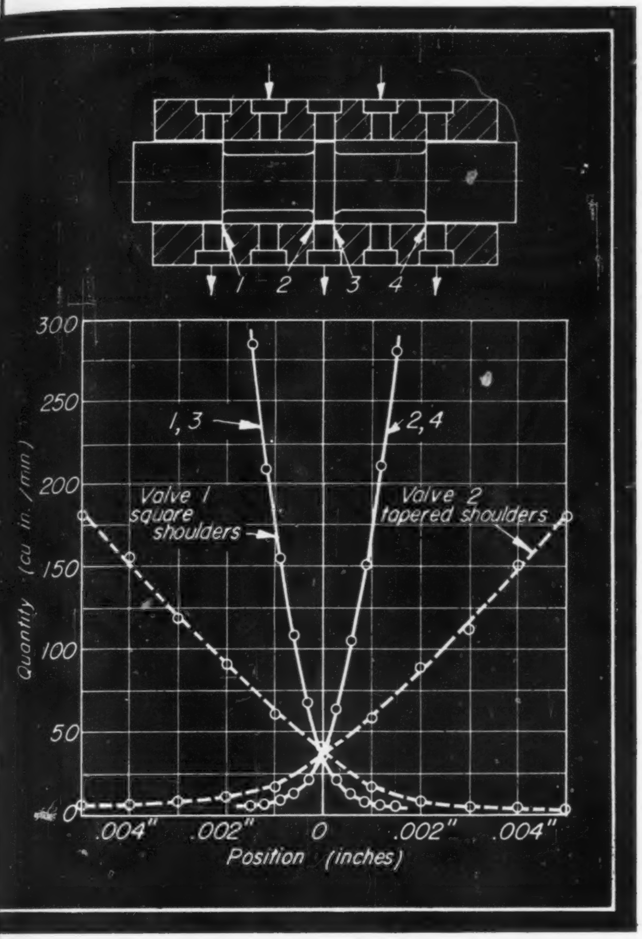


Fig. 43—Above—Valve movement plotted against oil passed indicates sensitivity of two servo valve designs

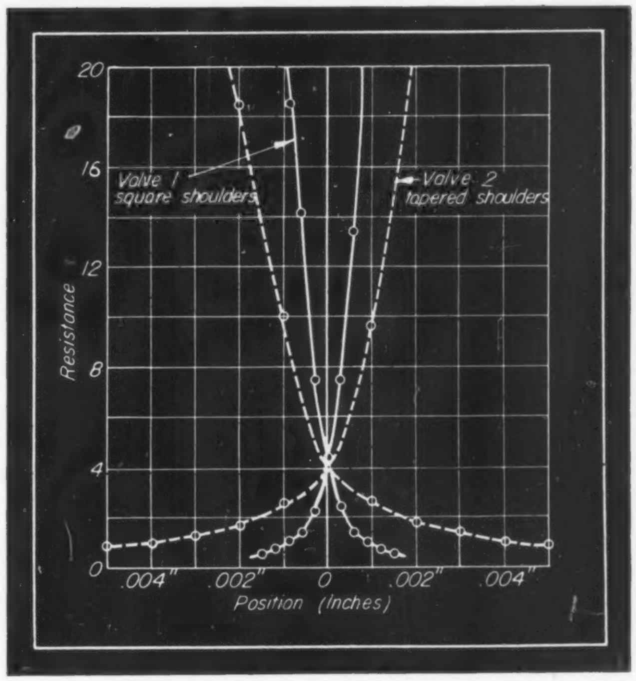


Fig. 44—Right—Characteristics of valves in Fig. 43 plotted in terms of resistance units versus valve movement

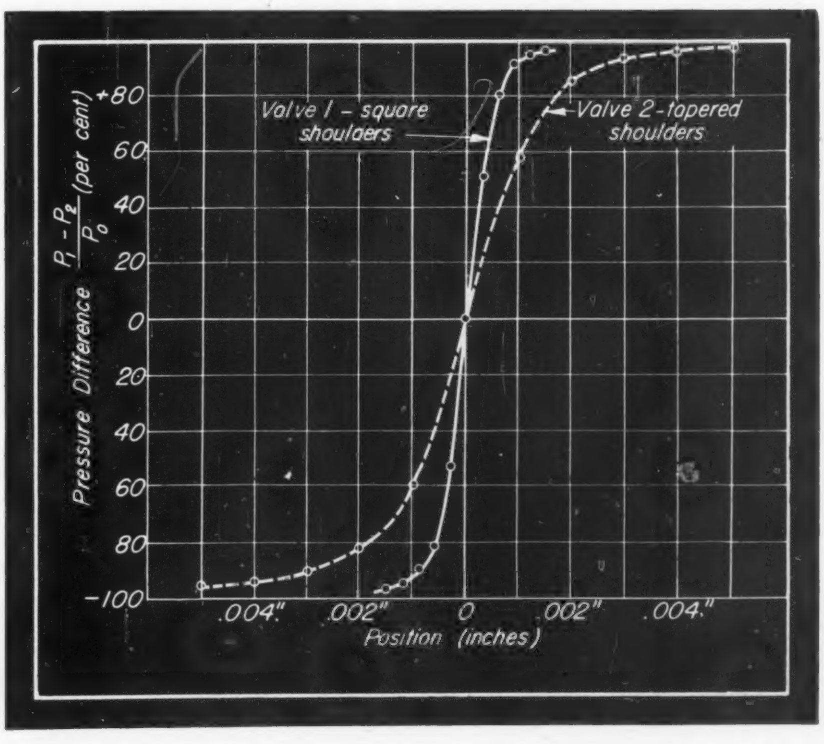


Fig. 45—Below—Valve movement plotted against pressure differences indicates high sensitivity of this type valve

later. This vibration is sometimes referred to as "dither" and serves the purpose of keeping the moving parts "alive".

Servo Feed-Backs: A variety of feedbacks has been employed on machine servos, the simplest form of which is shown in *Fig.* 41. The differential action, it will be recalled, is obtained by making the bushing and slide integral. This feed-back has the advantage of great rigidity but, on the other hand, has the disadvantage that it requires too much space.

Another feed-back, shown in *Fig.* 46, has a bushing and valve which travel in a circular path. The member in which the bushing is placed is connected to the slide by means of a rack and pinion while the valve is actuated by a pin and lever connected to the handwheel. A unique feature of this arrangement is that the servo valve centers itself with respect to the bushing. This is done by closing the ends of the bushing and hydraulically connecting the closed ends to the necks of the pistons. The inlet pressure ports are placed toward the outside of the valve.

Application of the pressure difference on the valve necks to the ends of the valve itself serves two purposes. First, it makes the valve action independent of backlash in the feedback. Secondly, the operator of the handwheel feels a small percentage of the load. This percentage of load on the handwheel to the load at the slide depends on the ratio of effective area of the slide motor to that of the servo-valve end. Mechanical connection between the handwheel and servo valve must not be self-locking and the friction in the handwheel must be low, as must be the

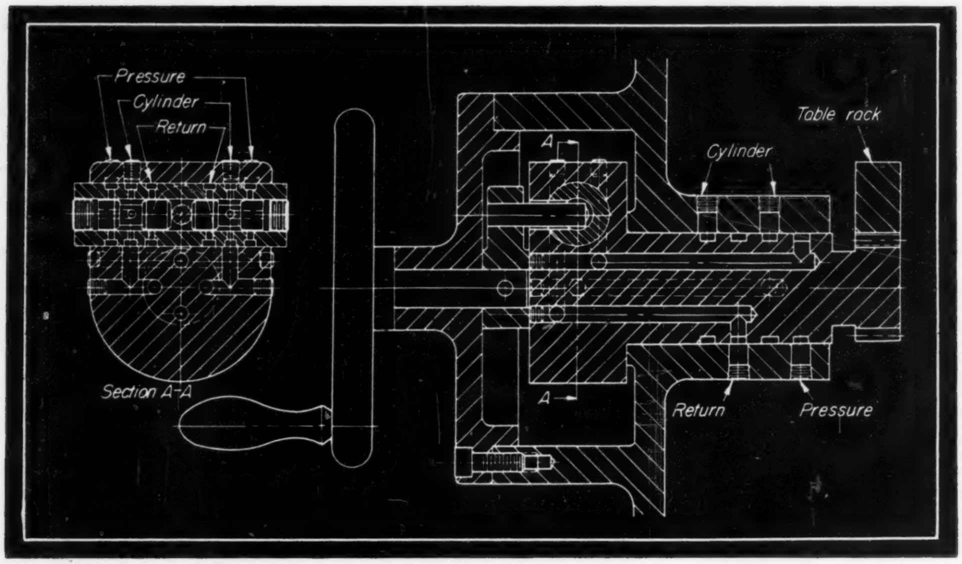


Fig. 46 — Feedback servo valve to operate heavy slides under hand control has advantage of "feel"

mass moment of inertia, in order to preclude local oscillation between the servo and handwheel. It is possible with this system to move a slide in increments of 0.0001-inch, even when a relatively insensitive valve is used. Sustained oscillation of the slide cannot occur when the centering force is great enough to carry the handwheel with it at all times.

Contour Tracing: Probably the most important application of the servo valve to machine tools is its use in contour tracing. In *Fig.* 47 is shown the simplest type of tracer, which is designated the 180-degree tracer. In this tracer, the axis of the tracer finger is in the plane of the contour. The slide movement, which is parallel to the axis of the tracer finger, is controlled directly by the tracer valve, while the slide movement at right angles thereto is reduced in accordance with the tracer deflection. There are three basic positions of the tracer finger which have been named arbitrarily: Over-deflected, neutral and undeflected.

When the tracer, shown in *Fig.* 47, is undeflected, the valve is so ported that the slide moves downward. When the tracer is in the neutral position no vertical movement takes place, while the over-deflected position causes the slide to move upward. Thus the tracer is always seeking contact with the master. When a sharp slope is encountered, the horizontal component of movement is decreased by the throttling ports at the top of the valve. When a vertical slope is encountered, the horizontal component is stopped by the closing of these throttling ports. It is apparent that contours which exceed 180 degrees of included angle cannot be traced.

In a 360-degree tracing method, the axis of the tracer finger is placed perpendicular to the plane of the contour, shown schematically in *Fig.* 48. The tracer valve is used only as a directional servo and corrects for direction of motion only, the feed components being determined by the other means shown which are in turn controlled by the tracer mechanism.

Tracer Seeks Tangent to Master

To obtain this result the tracer finger is made eccentric to the main tracer axis. Geared to the tracer body, *Fig.* 48, is another eccentric which controls the setting of the feed control valves or directional valves. In operation, if the direction of the tracer eccentric is such that it interferes with the master, the tracer overdeflects which causes the servomotor to rotate the tracer counterclockwise. This reduces the tracer deflection and at the same time corrects the angle at which the directional eccentric is pointed. Thus the feed components are corrected to give the proper direction. In this way, the motion of the tracer assembly with respect to the master is always seeking a direction which is tangent to the curve of the master.

A traverse cylinder, *Fig.* 48, controls the table on which the master and work are mounted, while the "in" and "out" cylinder controls the ram upon which the tracer and cutter are mounted. The rate of feeding is controlled by the magnitude of the eccentricity of the feed cam or eccentric. In this type of mechanism the servo can be extremely sensitive, since any "dither" in the servo mechanism will have only a secondary effect on the slides. It has been found that a vibration of low amplitude and high

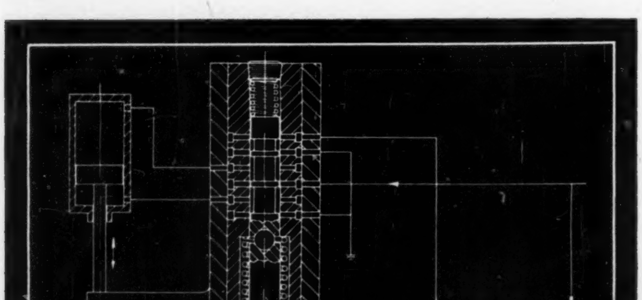
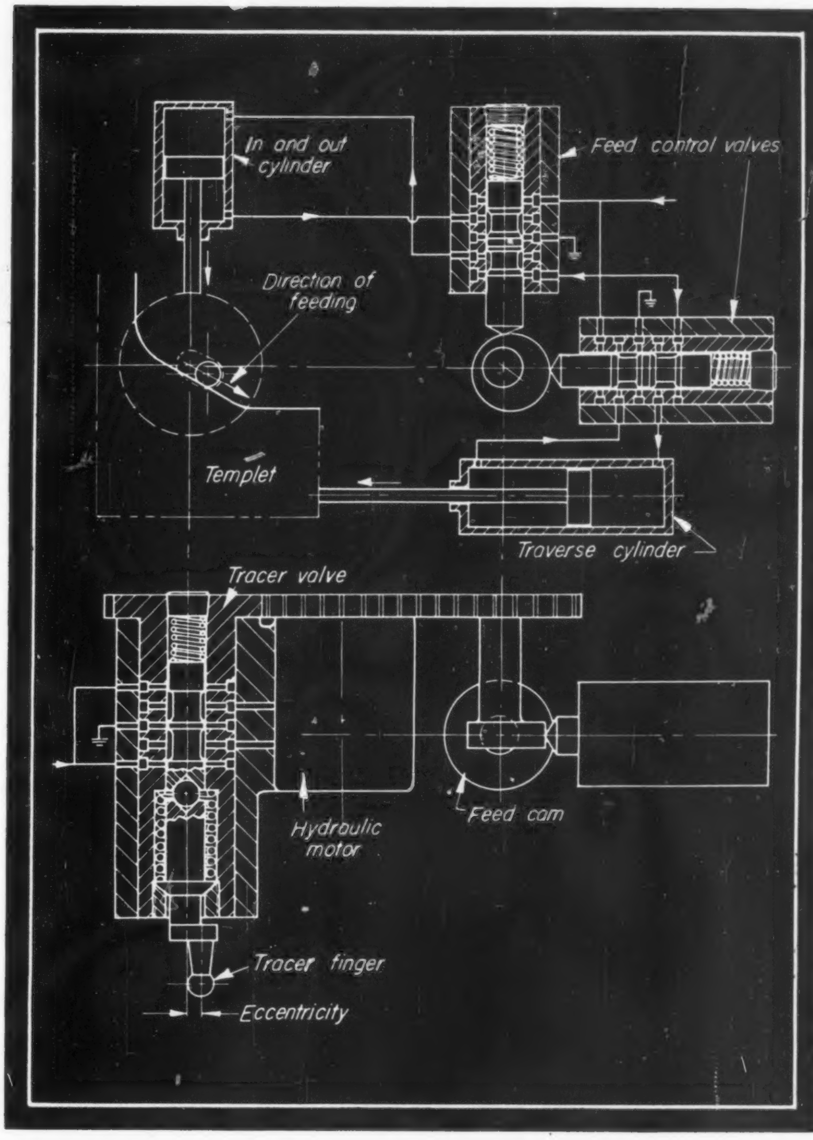


Fig. 47—Left—Hydraulic tracer for 180-degree contours controls axial movement directly and movements normal to the tracing finger by deflection

Fig. 48—Right—Tracer servo for 360-degree contours serves to correct direction of motion only



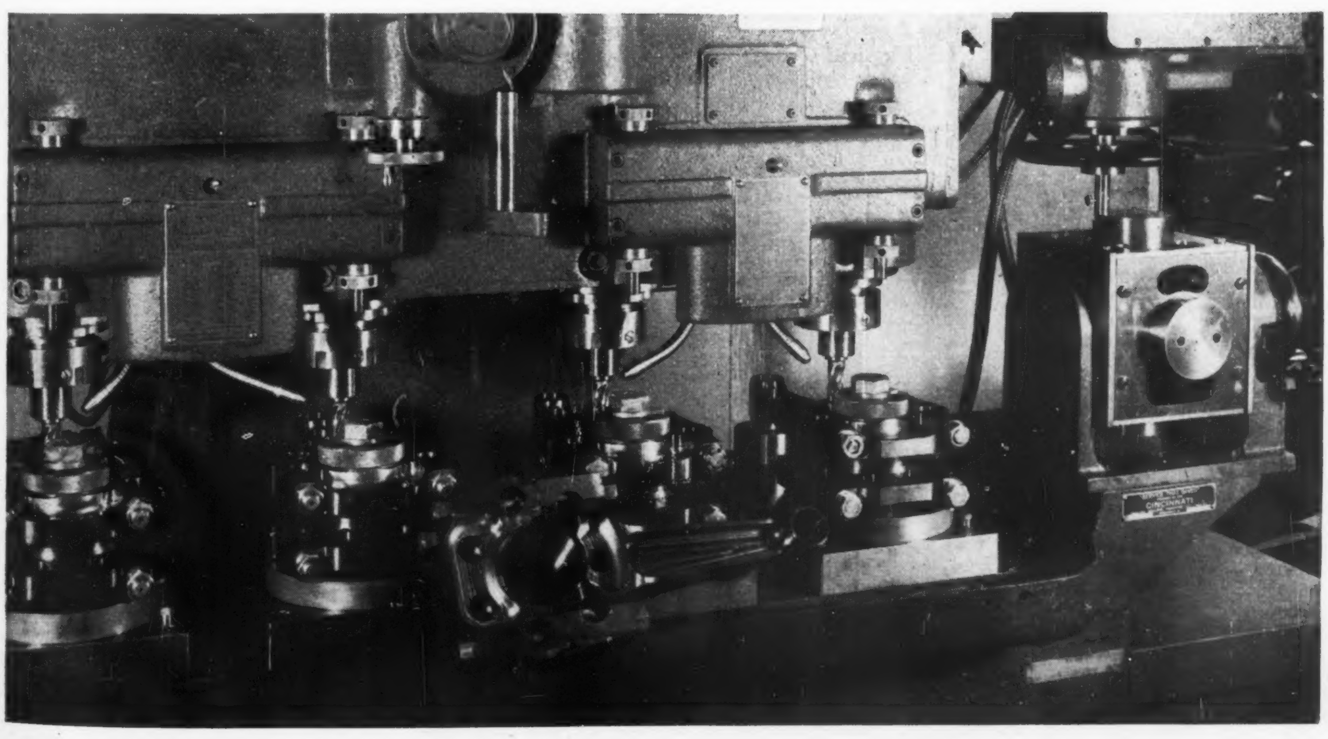
frequency will not affect the slides and at the same time increases the accuracy of tracing.

A machine for die sinking and similar nonuniform contour work which utilizes the 360-degree method of contour tracing is shown in *Fig.* 49 arranged for milling various shapes on the master rod for a radial engine. Rod design involves the contouring of several distinct shapes which are performed in sequence by means of masters which are incorporated in an index fixture.

A machine for milling cooling fins on cylinders for radial engines is shown in *Fig.* 40. Here a multiplicity of shapes or contours is needed for the fins at various levels. The tracer used in this instance, and which can be seen at the right, is a disk equal in diameter to the milling cutter used. The master on which this tracer operates consists of a stack of narrow cams formed to the proper shape for each level.

Sixth and last part of this series of articles, which will appear in a forthcoming issue, will cover trouble shooting and maintenance problems on machine hydraulic systems.

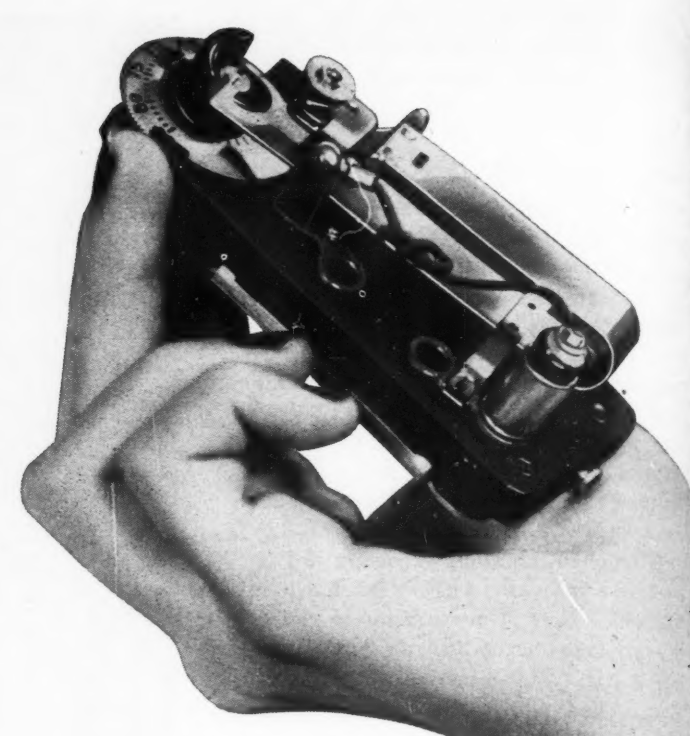
Fig. 49—Below—Contour milling machine which employs the 360-degree method of tracing from a master



By C. F. Alban
Chief Engineer
W. M. Chace Co.
Detroit

Thermostatic Bimetals

The design of actuating elements for temperature responsive devices



THERMOSTATIC bimetal is a material of considerable value to the mechanical designer. Properly used it may control temperature or electric current within extremely close limits, *Fig.* 1. It may serve as the basic element of servo mechanisms or remote control devices. Wherever applied, it offers the advantage of simplicity of design and ease of operation.

A composite metal of two or three laminations having different thermal expansion rates, bimetal strip is made by a direct high-temperature, high-pressure welding process without the use of any bonding material. By using this welding method the strength of the welded junction is no longer a factor limiting the use of the material.

When bimetal is heated it bends in the arc of a circle, and a definite curvature can be used to indicate temperature change. The force developed by restraining this de-

Fig. 1—Above—Typical application of bimetal strip in temperature control. Cam-controlled strip is of the U type

TABLE I

Physical Properties of Thermostatic Bimetals

Type No.*	Temp. Range (Deg. F)	Deflection Constants Straight Strips (×10⁻⁷)	Deflection Constants Coils (×10⁻⁶)	Flexivity (×10⁻⁶)	Torque Constant k Strip at 80 F (×10⁵)	Torque Constant k Coil at 80 F (×10³)	Modulus of Elasticity (psi)	Resistivity (ohms/cir mil ft at 80 F)	Resistivity (ohms/sq mil ft at 80 F)
6850.......	—100 to 500	78	100	15.0	47	27	19000000	850	670
6650.......	—100 to 500	107	136	20.6	47	27	19000000	675	530
2400.......	—50 to 500	77	95	14.6	62.5	35	25000000	480	380
6400.......	—50 to 500	77	95	14.6	62.5	35	25000000	400	315
6350.......	—50 to 500	77	95	14.6	62 5	35	25000000	350	275
6300.......	—50 to 500	77	95	14.6	62.5	35	25000000	300	235
6250.......	—50 to 500	75	93	14.2	62.5	35	25000000	250	197
6200.......	—50 to 500	74	91	14.0	62.5	35	25000000	200	158
6175.......	—50 to 500	72	89	13.6	62.5	35	25000000	175	137
6150.......	—50 to 500	70	85	13.0	62.5	35	25000000	150	118
6125.......	—50 to 500	67	82	12.4	62.5	35	25000000	125	98
6100.......	—50 to 500	57	70	10.7	62.5	35	25000000	100	79
3300.......	—50 to 350	52	64	9.8	65.0	37	26000000	95	75
3600.......	—50 to 700	59	72	11.0	62.5	35	25000000	407	320
3700.......	—50 to 600	68	80	12.2	62.5	35	25000000	430	338
4000.......	—0 to 1000	41	48	7.3	62.5	35	25000000	430	338
2100.......	—50 to 500	70	86	13.2	62 5	35	25000000	477	375
2300.......	—50 to 700	62	76	11.8	62.5	35	25000000	413	325
2500.......	—50 to 800	31	37	5.7	62.5	35	25000000	350	275
2550.......	—50 to 500	50	62	9.5	62.5	35	25000000	331	260
2600.......	—50 to 500	68	81	12.4	62.5	35	25000000	510	400
2800.......	—50 to 700	54	65	10.0	62.5	35	25000000	430	340
3500.......	—50 to 700	50	60	9.2	62.5	35	25000000	400	315
4300.......	—50 to 500	38	48	7.2	61	34	24500000	270	212
4700.......	—50 to 500	55	66	10.0	65	37	26000000	510	400
5200.......	—50 to 500	45	54	8.3	64	36	25500000	600	475

* Type designations of W. M. Chace Co. Bimetal materials as yet have not been standardized.

flection provides a simple, reliable and compact means of transforming heat into mechanical movement. Heating may be the result of electrical heating by induction or resistance, or by conduction, convection, or radiation. Alloys having the proper physical properties, including widely differing expansion coefficients, are utilized and selection is dependent upon the properties required in the thermostatic bimetal. These properties may include high deflection, high torque, low deflection and electrical resistivity.

APPLICATION: Keeping in mind that the fundamental property of thermostatic bimetal is to change heat into mechanical energy, the design problem resolves itself into determining the best way of applying the available force. Indicating the various mounting methods possible are *Figs.* 2 and 3 which show a few applications of thermostatic

TABLE II

Working Stress Values

Temperature (Degrees F)	Stress† (psi)
—100	25,000
100	25,000
200	23,000
400	20,000
600	15,000
800	12,000
1000	7,000

† Working stress (*f*) should not exceed the above values for temperatures up to 1000 F.

bimetal. Mechanical loading of bimetal must be within the elastic limit of the material. Sufficient temperature change must be provided to assure the necessary thermal deflection to do the work required.

Thermal deflection may well be linear, rotary, or endwise. The forces developed may be used to produce changes in torque, tension, or compression. Parts can be designed to give a maximum output of work for a given temperature change and to occupy a minimum space for certain conditions. Parts may be stampings, formed elements, spiral or helical coils, and be spot welded or silver-solder brazed to brackets or shafts, or carry welded or brazed flexible cables, terminals or contacts.

The simple way in which thermostatic bimetal acts makes it applicable for an unlimited number of devices that function as temperature indicating or controlling means. It lends itself readily for use as a flat strip, "hair pin" or "U" shape, disk or coils. The coil is especially adapted to the dial type of device. The "U" shape makes it possible to secure maximum movement in a limited amount of space. In order to provide as great sensitivity as possible for a definite working range, several types of thermostatic bimetal are available. High or low- temperature applications can best be met by selecting a type that gives the greatest sensitivity within the desired working temperature. Thermostatic bimetal, to have proper resiliency and strength, is given a certain amount of cold rolling in the manufacture. Internal stresses are set up which should be removed by heat treatment, before putting the parts into service. The working temperature and the maximum temperature that the bimetal element will be subjected to determine the type of material to be selected. In general, the most sensitive type within the required range is selected, as it reduces the size of the piece to a minimum. When a wide range of adjustment is desired in a small space, a less sensitive bimetal may work out the best. By referring to the physical properties, TABLE I, a comparison between types readily can be made.

FLEXIVITY:* Flexivity, *F*, is the change in curvature of the longitudinal center line of the specimen per unit temperature change and unit thickness, for a condition such as illustrated in *Fig.* 4. Flexivity is given by the formula

$$F=\frac{\left(\frac{1}{R_2}-\frac{1}{R_1}\right)t}{T_2-T_1} \qquad \text{(1)}$$

The curvature is, by derivation,

$$\frac{1}{R}=\frac{8D}{Q^2+4Dt+4D^2} \qquad \text{(2)}$$

By substituting Equation 2 in Equation 1

$$F=\frac{8t}{T_2-T_1}\left(\frac{D_2}{Q^2+4D_2t+4D_2^2}-\frac{D_1}{Q^2+4D_1t+4D_1^2}\right) \qquad \text{(3)}$$

Where R = radius of curvature, in inches, t = thickness in inches, T = temperature, in degrees Fahrenheit, D for point supports = perpendicular distance, in inches, between the longitudinal center line of the lower surface of the specimen midway between the point supports and the straight line joining the support points, D for knife-edge supports = perpendicular distance, in inches, between the longitudinal center line of the lower surface of the specimen midway between the knife-edge supports and the plane passing through the knife-edges, but corrected for cross-curvature by multiplying by the factor

TABLE III

Standard Dimensional Tolerances for Bimetals

Thickness (inches)	Tolerance (inches±)	Width (inches)	Tolerance (inches±)	Length (Feet)	Tolerance (inches±)
0.005-0.010	0.00035	0-½	0.003	0-1	$\frac{1}{32}$
0.010-0.015	0.0004	½-1	0.004	1-3	$\frac{1}{16}$
0.015-0.020	0.0005	1-6	0.008	3-6	$+\frac{1}{2}, -\frac{1}{16}$
0.020 and up	±2½%				

$$\frac{1}{1+\left(\frac{W}{Q}\right)^2}$$

where W = width of test specimen in inches. TABLE I gives flexivity and other physical properties for a number of bimetals.

DEFLECTIONS: The deflection of a bimetal strip with one end fixed, measuring the movement of the free end at right angles from the cold position, varies with the square of the length, inversely with the thickness and, for practical purposes, in direct proportion to the temperature change up to a predetermined temperature limit. For example, a piece eight inches long would have four times the deflection of a four-inch length, while a piece two inches long would have just one-fourth the deflection of a four-inch length. Reducing the thickness on-half would double the deflection and doubling the thickness would reduce the deflection by one half.

The angular deflection of a spiral or helix varies directly

* ASTM Standard B106-37T.

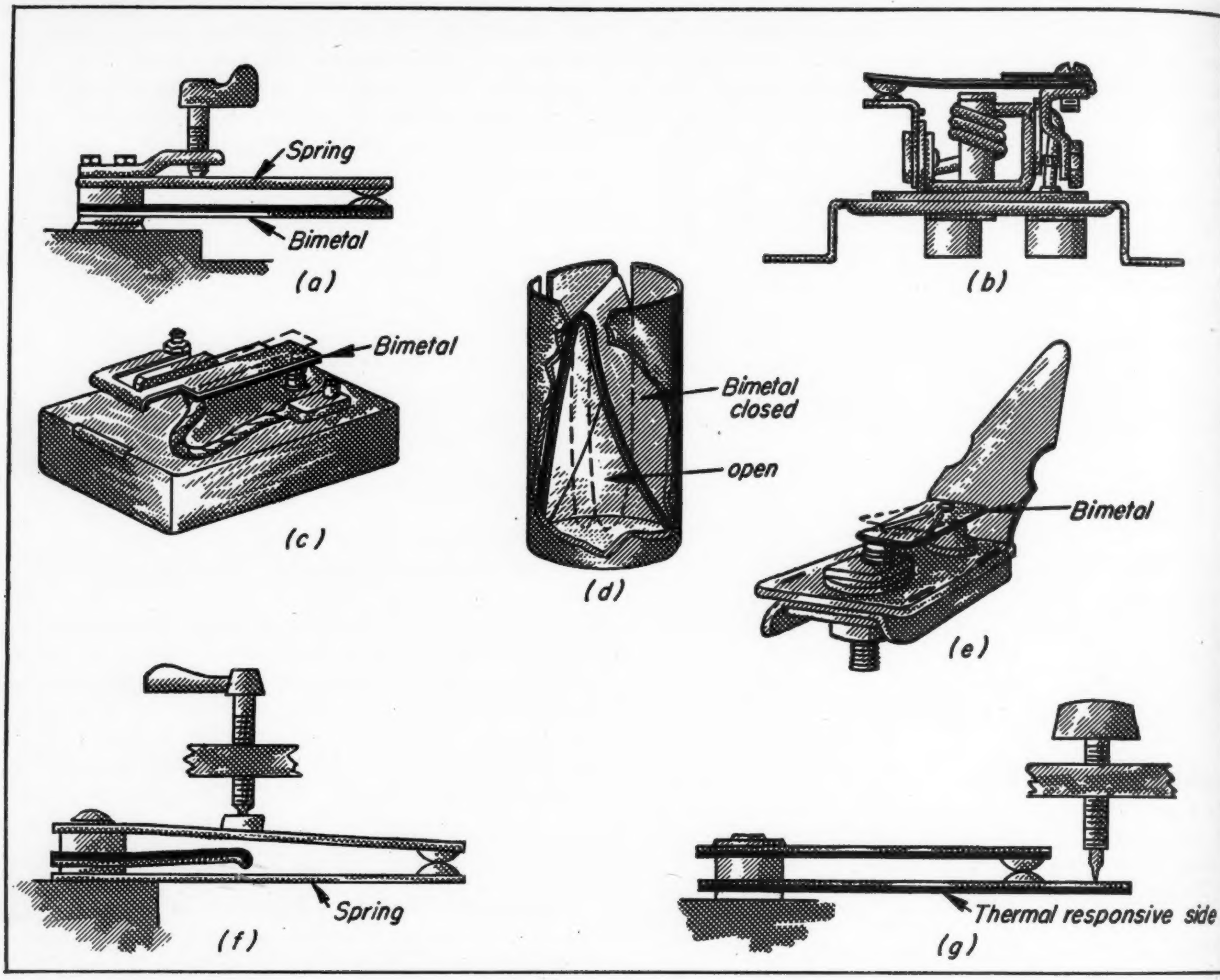


Fig 2—Typical thermostatic devices illustrating the correct use of bimetals. (a)—Simple leaf-spring contact with adjustment. Since black side of bimetal is the thermally responsive side, strip will deflect away from contact on heating. (b)—Rapid-cycling current-limiting device consisting of solenoid with coil designed to heat up. Circuit is so designed that bimetal deflects and opens contact when current flows through and heats coil. (c)—Somewhat similar to (b), this is also a rapid-cycling current-limiting device of the circuit-breaker type. (d)—Exhaust by-pass valve of the double-leaf type, useful for the control of fluid flow as in engine manifold. Normal position is with vanes spread. Increase in fluid temperature closes vanes, opens valve. (e)—Simple bimetallic switch with upper member deflecting upward with increase in temperature. (f)—Switch where bimetal is kept out of electrical circuit thus avoiding electrical heating.. (g)—Highly sensitive switch where deflection difference opens contact. Screws allow adjustment

with the length of the strip, inversely as the thickness of the material, and in direct proportion to the temperature change. The number of turns or the diameter of either element does not affect the deflection materially. As far as angular movement is concerned, there is no appreciable difference between spiral and helix-wound coils of a given size strip. Coils may be formed to either wind up or unwind with increase of temperature.

It is desirable that sufficient room be allowed between turns so that under extreme temperature conditions there is opportunity for air circulation as well as mechanical clearance to avoid any friction or binding of the turns. For this reason it is recommended that coils be made to unwind with increase of temperature. Helical coils may be wound either right hand or left hand to give the desired rotation. Also, a helix which unwinds with increase in temperature has a slight elongation It is necessary that this be taken into consideration so that end thrust of the coil does not introduce friction into the linkage.

THRUST: Force exerted by the free end of a straight strip, assuming it to be under restraint due to a change in temperature, varies directly with the width of the strip and the cube of the thickness, inversely with the cube of the length and equals

$$P=\frac{kdbt^3}{l^3}$$

Deflection is equal to

$$d=\frac{k(T_1-T)l^2}{t}$$

where d = deflection of free end, in inches, $T_1 - T$ = temperature change, in degrees Fahrenheit, P = thrust in pounds at free end, t = thickness in inches, l = length, in inches, b = width of strip, in inches. This applies at

normal temperature and allowance must be made for elevated temperatures for under such conditions the strength of the material is greatly reduced. The equations for thrust of a helix are, of course, similar. If to the above values we add: A = angular rotation, in degrees, r = radius of helix, and k = torque constant selected from Table I, then, thrust of a helix or spiral equals

$$P=\frac{kAbt^3}{lr}$$

and rotation is equal to

$$A=\frac{k(T_1-T)l}{t}$$

In the formula given for calculating the thrust or pull of either spirals or helices, the radius may be selected as the distance from the center to the point at which the load is applied.

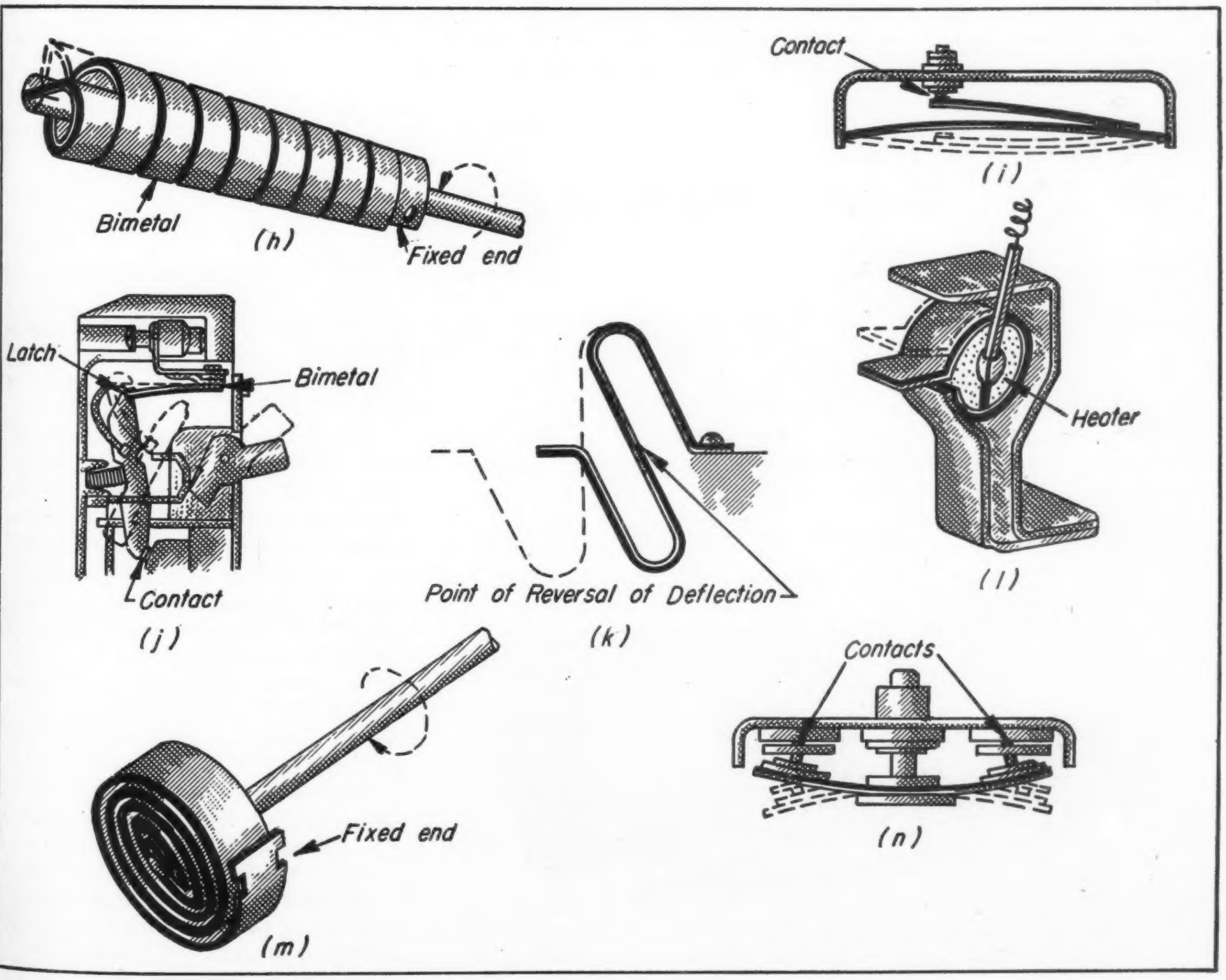
Maximum Load: To avoid deformation of bimetal elements in service, care should be taken that the stress produced does not exceed maximum values. The following formula is given for calculating the maximum stress for either strips or coils.

$$f=\frac{6Pr}{bt^2}$$

where f = working stress, psi, P = load in pounds, r = radius of the coil or moment arm, in inches, b = width, in inches and t = thickness, in inches.

The formula for estimating maximum stress in a helix or spiral is the same as for the straight strip. The turning moment is the same for both arrangements so that any limitations mentioned regarding the strength of a straight strip would also apply to spirals and helices. At elevated temperatures the strength is reduced. Table II shows maximum working stress values for high-temperature bimetal with respect to temperature. A reasonable factor of

Fig 3—Thermostatic devices of rotary type. (h)—Helical strip is used to rotate shaft, can be used to provide power or indicate temperature. With bimetal applied as indicated, helix will close in heating. (i)—Snap type of bimetal switch useful in reducing arcing. (j)—Circuit breaker. Bimetal serves as latch holding contact containing link in closed position. (k)—Schematic indicating design of bimetallic strip for high deflections. (l)—Device for remote control of units by electric current. Electrical heater, powered from remote source, causes bimetal to deflect in proportion to the current input. With proper design of heater element, deflection will be linear. (m)—Another type of rotating shaft device has strip wound in spiral. Design shown will cause spiral to close in heating. (n)—Double contact switch consists of bimetal strip supported in center. Contacts may be insulated from or in circuit with bimetal



safety based on years of performance in service has been selected.

PHYSICAL DIMENSIONS: Dimensions of the bimetallic material have been reasonably well standardized. Dimensional tolerances with regard to thickness, width and length are given in TABLE III, while TABLE IV gives the standard and minimum strip widths for the various thicknesses of metal.

HEAT TREATMENT: In order to give stability to the element after it is cut and formed, a heat treatment is necessary. This can be done in an ordinary electric or gas-heated oven. It is recommended that the heat treatment consist of one three-hour period. After the heating, pieces should be removed and allowed to cool in air to room temperature. Owing to the movement of the metal when subjected to heat, care should be taken that the parts are free in the oven so as to permit natural deflection without the metal being restrained by such devices as clamps and fixtures thus producing internal strains and very likely erratic instruments.

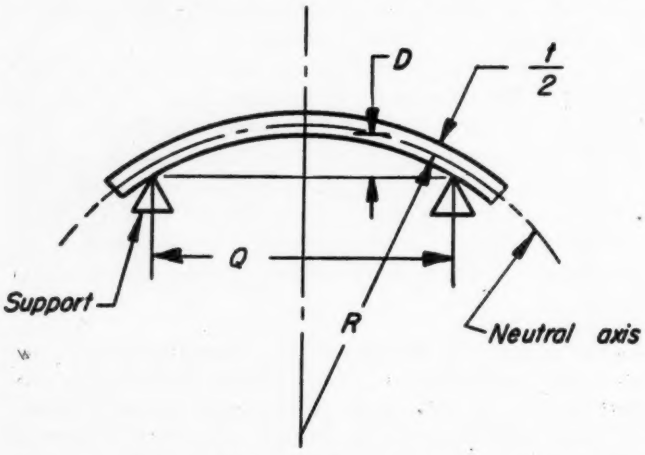


Fig 4 — Relationship of dimensions in heat-deflected bimetal strip. D depends on method of strip support

TABLE IV

Strip Widths for Bimetals*

Thickness (inches)	Minimum Width (inches)	Standard Widths (inches)
0.005	3/32	2
0.010	3/32	2, 3
0.020	1/8	2, 3
0.030	5/32	2, 3
0.040	7/32	2, 3, 6
0.050	1/4	2, 3, 6
0.060	5/16	2, 3, 6
0.070	3/8	2, 3, 6
0.080	1/2	2, 3, 6

* Strip is also supplied in widths of 1/32-inch multiples, maximum length usually nine feet.

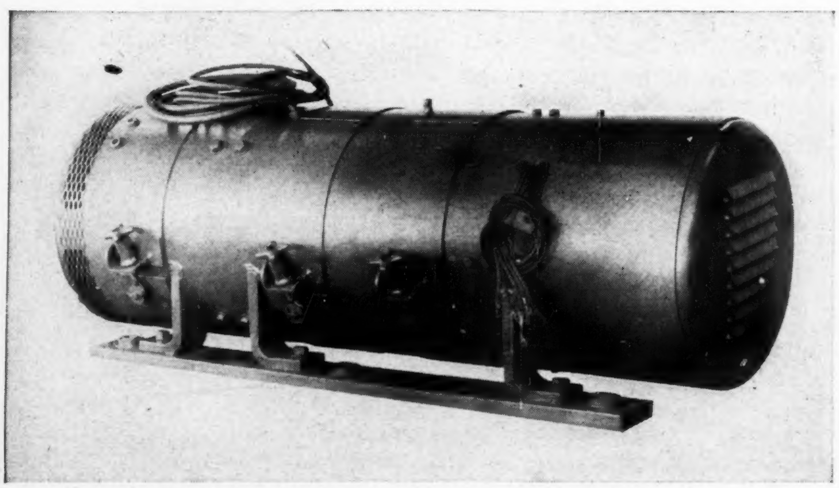
Heat treatment temperatures for various types of thermostatic bimetal range from 500 F to 1000 F, depending upon the type and application. For most work three hours at 700 F is a good value. If the operating temperature is in excess of 700 F, the heat treatment should be at least 100 degrees in excess of the maximum value that the material will be subjected to after it is installed. In general, because of the inherent limitations in physical properties of most bimetallic alloys, applications which require operating temperatures above 1000 F are not recommended.

Constant Voltage Supply for Railway Cars

PROBLEM OF PROVIDING a constant-voltage, sixty-cycle current for railway cars has been conveniently solved by the use of an amplidyne. (For amplidyne principle see "Precise Control Enhances Machine Performance," M. D. April 1943)

A partial answer to the demand for sixty-cycle current for electric razors, fluorescent lamps, etc., was the use of vibrating inverters for small power requirements and motor-driven alternators to satisfy higher load demands. However, the application of very high loads to these systems, such as the starting of large inductions motors for air-conditioning systems, resulted in voltage drop. When installations included fluorescent lights, flickering or even extinguishing resulted.

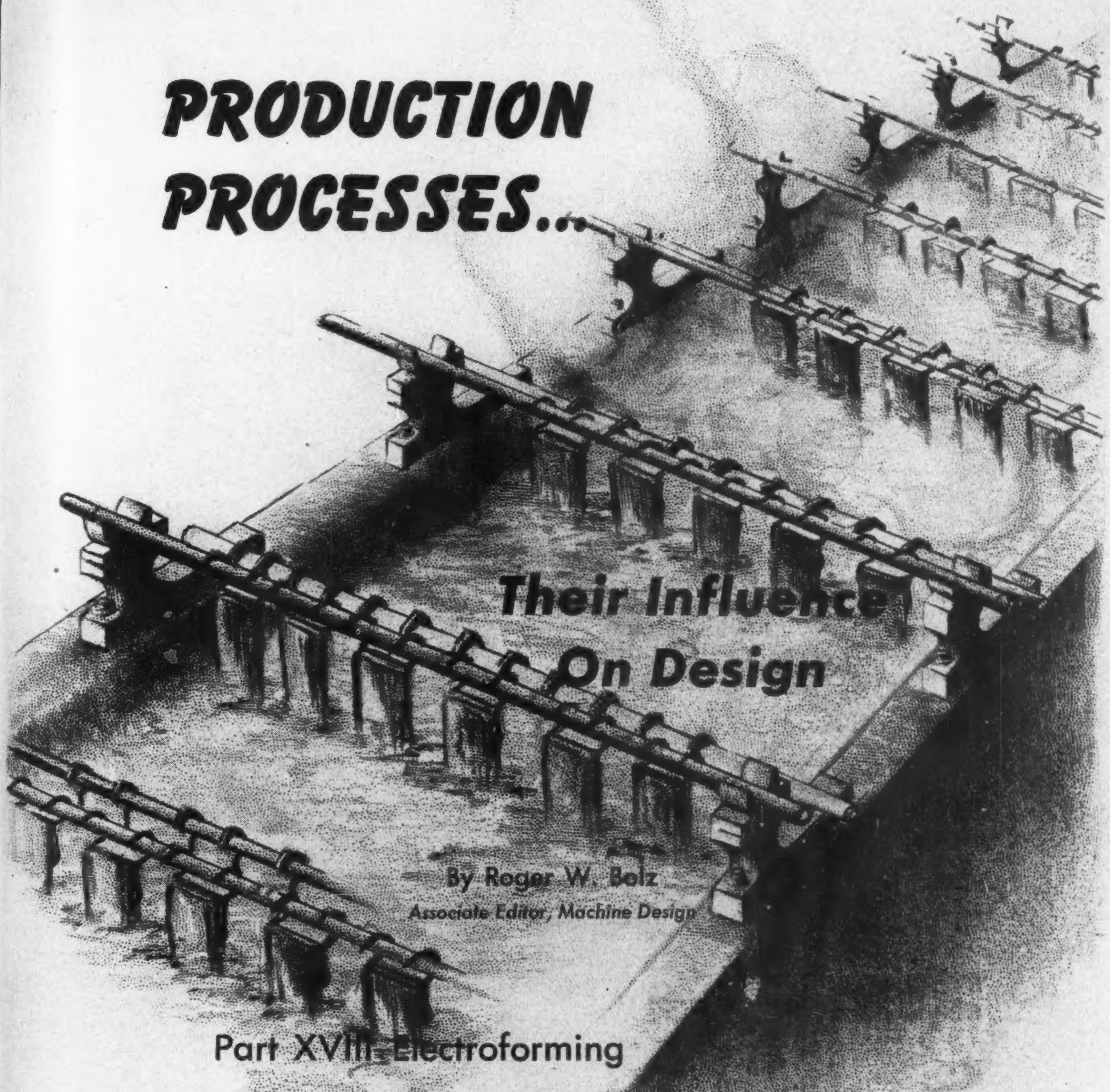
The amplidyne booster inverter, seen in the illustration, is a General Electric development which is in effect a synchronous converter running from the direct-current side, with an amplidyne mounted on the same shaft. The amplidyne is connected in series with the inverter and bucks or boosts the voltage supplied by the axle-driven generator or battery, to maintain constant alternating-current power on the output side of the inverter. Essentially, the booster inverter changes the current supplied by the railway car's power supply from direct to alternating, and gives constant voltage and frequency without excessive losses and with reduced maintainance.



In this manner, an ample economical supply of sixty-cycle power is supplied to passenger cars, providing a number of additional comforts and luxuries.

PRODUCTION PROCESSES...

Their Influence On Design



By Roger W. Bolz
Associate Editor, Machine Design

Part XVIII—Electroforming

RECENT developments in the electrodeposition of metals have definitely brought this somewhat obscure art into the category of precision manufacturing methods. Commonly known as electroforming when applied to the production of metallic parts by electrochemical deposition of metal, this interesting technique makes available to the design engineer the means for solving many complicated fabrication problems encountered in the design of present-day precision machines and instruments, *Fig.* 1.

Originated over a century ago by Jacobi, the process was first used to produce electrotypes and other similar articles. Later it was utilized to make sheet copper, seamless copper tubes, etc. More recent uses include the manufacture of sound record masters, filter screens up to 400 mesh per linear inch, jointless radiators, caskets, reflectors, pipe fittings, seamless copper tanks, floats, and transformer cores. The advent of successful electroforming with iron brought into the picture the economical mass production of complicated dies such as those used in molding tires, glass and plastics as well as for embossing and die casting.

The steady trend toward more exacting tolerances in late years as well as the previously unheard of requirements presented by war-born design such as that found in radar and microwave equipment, gun sighting and computing mechanisms, electronic and mechanical calculating machines, etc., have helped to promote the utilization of the electroforming process, *Fig.* 2. In addition to making possible the production of parts with highly exacting repetitive dimensions, this method also makes available a quality surface finish not possible by ordinary mass machining methods. This is especially valuable where such surfaces required are internal and irregular — often impossible to produce otherwise at any cost. Such parts might be precision telescopic tubing, round and rectangular waveguides, tee sections, tapered and twisted sections, resonators, irregular shapes, bellows, etc., *Fig.* 3.

Electroforming—unlike electroplating which seldom involves deposits over 0.0001-inch in thickness intended

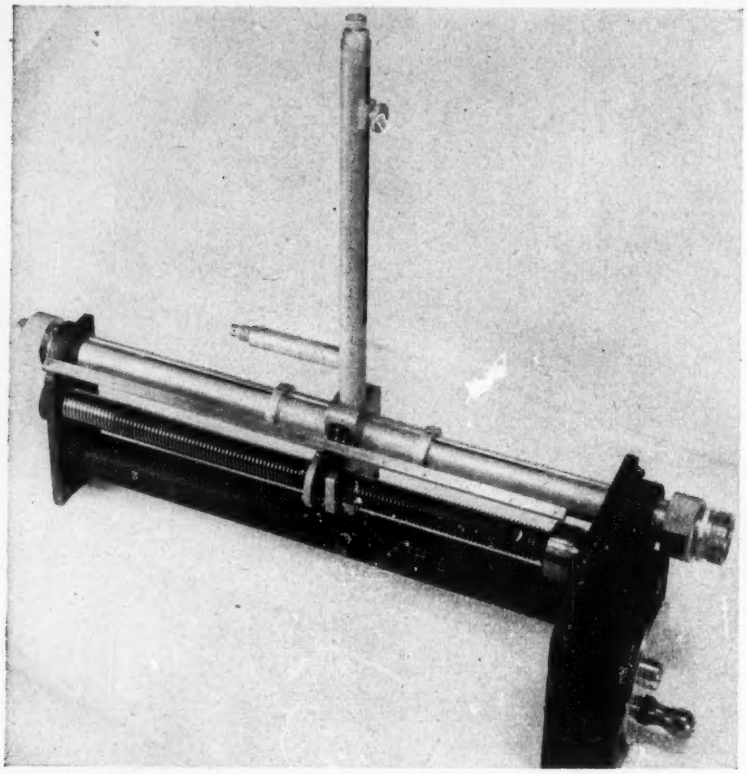


Fig. 1—Above—Microwave impedance meter, coaxial line and travelling carriage of which are electroformed telescopic tubing

Fig. 2—Below—A wavemeter with a micrometer waveguide feed. The precision resonator of the unit is electroformed

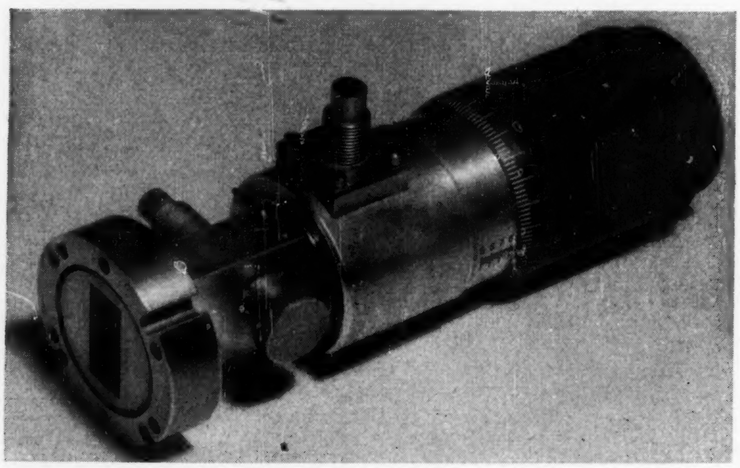
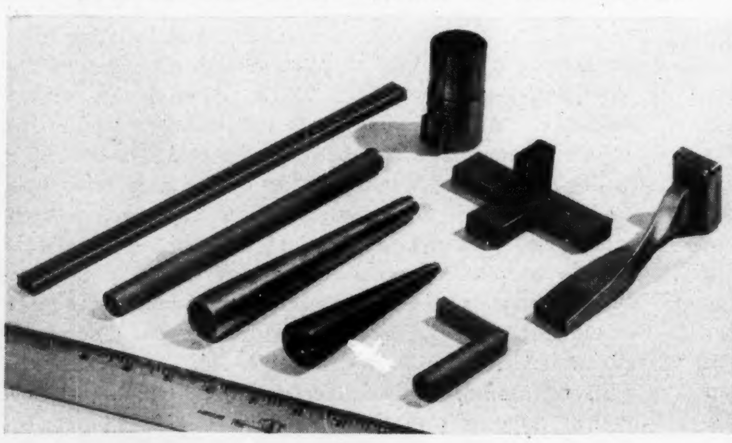


Fig. 3—Below—Group of electroformed radar components including tapers, bends, twists, magic tee, wavemeter body, etc.

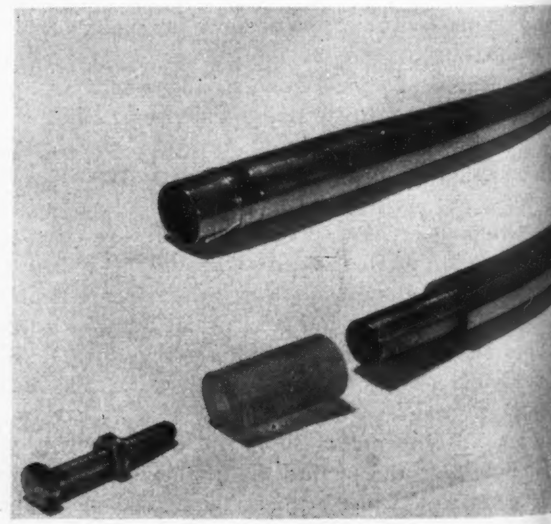


for protection or decoration—consists primarily of producing irregular mechanical parts by a process of electrodepositing metal on a master mold or matrix to a thickness consistent with the mechanical design requirements. The mold or matrix, a negative impression of the finished part, is of prime importance for it naturally determines the accuracy of the parts produced both as to dimension and surface finish.

A variety of methods for providing satisfactory molds or matrices are available. These can be broken down into two major groups, i. e., reusable and expendable. The reusable types are used for uniform cross sections or tapers which will allow the withdrawal of the master pattern without destroying it. This is accomplished in two ways: (1) With a separating medium or (2) by relying on poor adherence of a conductive coating. Separating mediums employed with reusable steel patterns may be thin films of low-melting point metals such as tin or cadmium. Where a negative steel master can be made easily by machining, it is finished undersize, plated to size with, say, tin and the desired metal deposited to the proper thickness thereon, *Fig.* 4. By heating the finished electroform above the melting point of tin in a wax, oil or lead bath, the pattern can then be withdrawn. The separating medium can be used in thicknesses from one-millionth of an inch up, although 0.0002 to 0.001-inch is the usual amount mandrels are made undersize, depending upon the application. Where a complicated master pattern such as a spiral computing mechanism cam, which takes many hours to produce, is to be used, production electroforming matrices can be made by plating this master with a thin parting film and electroforming on the master the required number of iron negatives. These negatives, then, serve as matrices for producing finished parts, *Fig.* 5.

Poor adherence mandrels or patterns usually are made of glass, Kovar or some other material having a relatively low coefficient of thermal

Fig. 4—Below—Reusable tapered steel pattern with masking caps and bolt. Electroformed part after finish machining operations is shown at top



expansion, *Fig.* 6. Surfaces of nonconductors are made conductive by spraying or dip coating with silver. This extremely thin coating becomes an integral part of the electroformed work when completed because of good adherence between the silver and the electroformed metal. Removal is effected by heating the assembly to about 600 F. Inasmuch as the silver and electroformed part expand about twice as fast as the mandrel and the silver adheres but slightly to the highly polished mandrel surface, the part comes off easily. A sprayed coating is required for low-expansion metallic patterns also to provide a poor adherence film for easy removal. Outstanding advantage of the glass patterns or mandrels is the surface perfection obtainable by optical methods of grinding and polishing.

Expendable matrices or patterns generally are used to produce parts of irregular shape, namely those whose design does not permit withdrawal of the matrix after completion—where it must change form radically to allow removal. These can be of several varieties: (1) Dissolvable metals or, (2) fusible metals or waxes. Matrices of the former type can be of commercially pure aluminum, which can be dissolved out with sodium hydroxide; cold-rolled steel or zinc, which can be dissolved out with hydrochloric acid, etc. Value of the dissolvable matrix is realized in applications where parts with extremely thin walls would be distorted by heat or where the matrix must be mechanically stronger and harder than the fusible metals and waxes.

Fusible metal, *Fig.* 7, and wax matrices or patterns are produced, as a rule, in a master die—steel, plaster, etc.—by casting. Fusible metals available can be had in a wide variety of melting points ranging from around 116.6 F to 350 F. Waxes used are rendered conductive by spraying with a metallic or graphite coating.

Fusible-metal matrices present some problems in production and these in addition to their instability at room temperature eliminate them from consideration in applications where the maximum in accuracy is necessary. First problem is maintaining good surface finish and the other is failure of matrix to melt out completely. Traces remaining inside parts after melting out must be brushed away or dissolved out in a bath, adding to the cost per part. However, since these metals and waxes can be easily and rapidly cast into matrices, fabrication of irregular machine components can be placed on a production basis most readily by this method.

Another type matrix or pattern which can be cast in a mold to produce either a conducting or a nonconducting base for electroforming is that of rubber. Rubber matrices are made conductive in much the same manner as are the waxes. Rubber matrices can be stripped and reused.

Electroforming is not an economical method of fabrica-

Fig. 5 — Right — Electroformed spiral pin-cam of nickel-faced iron for use in computing mechanisms

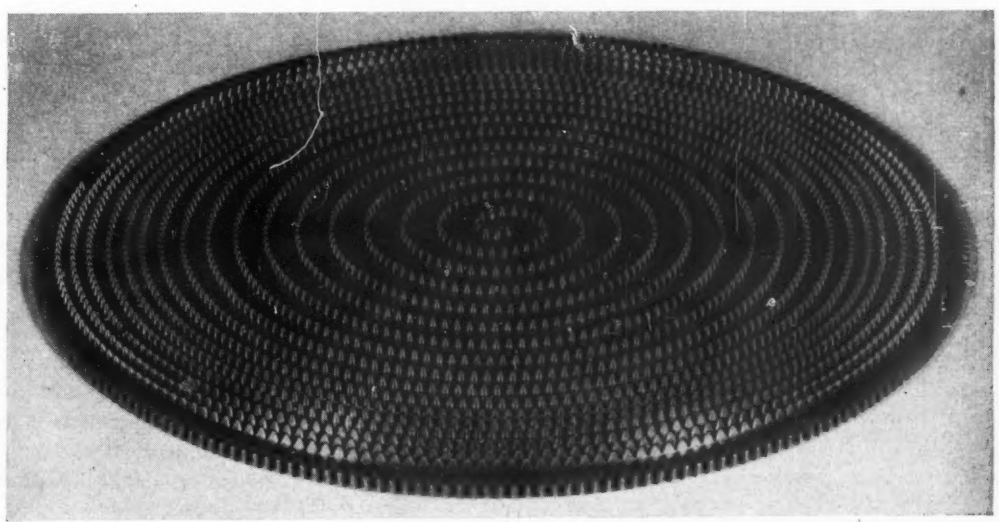
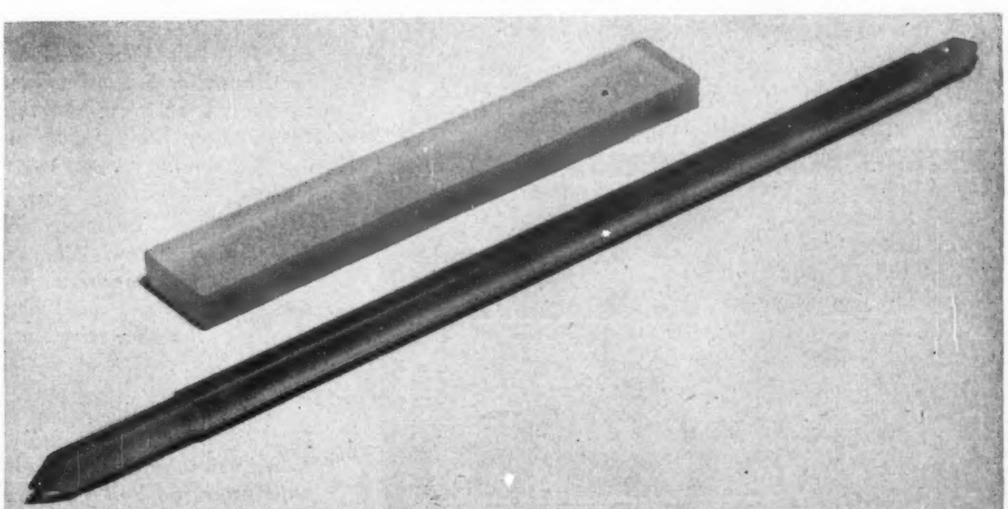


Fig. 6—Right Below—Typical glass mandrels for electroforming coaxial line and waveguide sections used in radar



tion, but being a high-precision process, in many cases it is less expensive than conventional precision machining processes. It is in application to those designs which are either totally impossible or extremely costly to produce by other methods that electroforming finds its most useful place. In the production of three-dimensional cams, spiral computing cams, and similar intricate, critically accurate mechanical components this process opens to the designer a field of possibilities hitherto found impractical.

Metal deposited in electroforming is essentially stress free, a condition conducive to dimensional accuracy over long periods of time. Machining of electroformed parts, for the same reason, produces little or no distortion. A large selection of materials readily available for commercial plating can be utilized. Layers or laminations of materials can be had such as copper on the inside for good conductivity and chromium on the outside for a durable, wear resistant surface. Where expansion problems are encountered, a conducting rubber film can be bonded to a part and a metal surface electroformed over the rubber.

In production the wall thickness on irregularly shaped electroformed parts as a rule will vary considerably unless special-shape anodes are used to maintain a uniform solution throwing power. A 0.050-inch section might vary as much as 0.020-inch and sharp corners usually build up heavily, *Fig.* 7. As a consequence, whenever possible, no exacting limitations should be specified as to wall thickness to achieve maximum economy. Corner build-up often is an asset to design in that additional strength and rigidity is achieved at no cost. When a part can be machined before removing the mandrel, *Fig.* 4, uniformity of wall thickness can be achieved most economically, but where uniformity without machining is essential, special handling often can be used to produce wall thicknesses desired. Maximum practical wall thickness is about ½-inch but there is almost no limitation to the thinness of wall.

Electroforming is adaptable to mass production of parts even though the making of one part is rather a matter of days more so than hours. Utilization of a multiplicity of matrices or forms and a great many plating tanks solves the problem. Production equipment is not elaborate, nor is it costly. The primary necessity for quality is control. Regardless of the size of production runs, cost per piece does not vary appreciably in electroforming—a characteristic unlike most other production methods.

Overall size limitations on parts is limited only by the size of plating tanks available. Parts from electroformed foil 0.00008-inch in thickness all the way to musicians 28-inch diameter kettle drums have been made successfully. The important consideration in achieving a satisfactory design is that of contour. Smooth, flowing contour renders the electrodeposition process much simpler. Metal cannot be deposited in a recess which is deeper than it is wide owing to attraction of the deposit to the point nearest the anode. Accompanying difficulties in achieving uniform wall deposits by means of special anodes is self-evident.

Design: Although somewhat limited in design possibilities, electroforming makes possible mass reproduction of uniform and irregular shapes to both a dimensional and duplicating accuracy not possible otherwise. An outstanding case in illustration is that of microwave instruments and transmission line components whose conducting surfaces are on the inside of the apparatus. To prevent reflections and excessive absorption of energy in this skin-

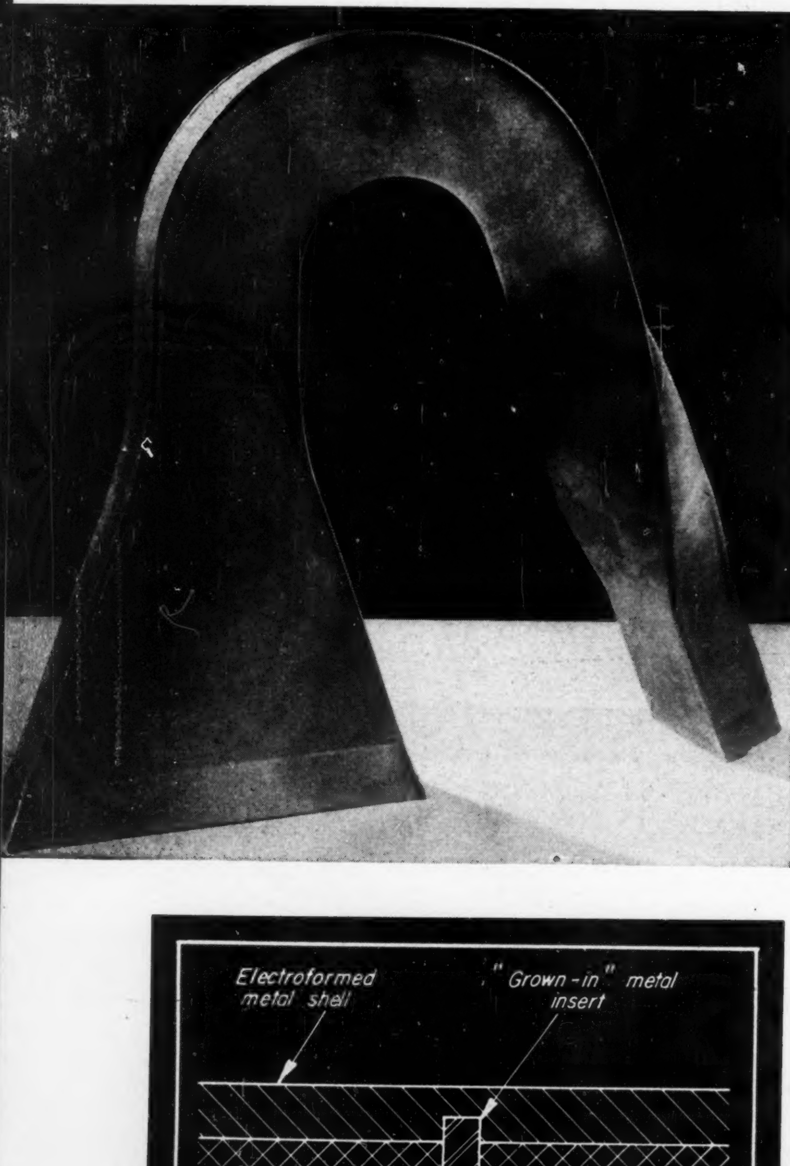


Fig. 7 — Left Above — Electroformed feed horn for S-band radar produced by means of a fusible-metal matrix. Note heavy build-up of metal along all the corner edges

Fig. 8—Left Below—Where a rib or boss is deemed necessary a metal insert can be used and "grown-in" at the desired point

Fig. 9 — Right — Electrically-heated pitotstatic tube for high-altitude aircraft produced by "grown-in" electroforming of the various components

depth layer, it must be extremely smooth and its contour held to highly exacting tolerances. Electroforming fulfills this requirement since the surface of the matrix—in this case an external one—is easily produced by ordinary methods to the tolerances necessary.

Delicate precision parts such as computing cams, *Fig.* 5, etc., which require many hours of machining and touching-up to achieve the precision operation desired, can by one of the methods previously described be produced in quantity with assurance of precision duplication from part to part. The only design requirement being that the part be easily removable from the matrix. Projections, therefore, should be specified with some taper whenever possible. Recesses should be avoided in favor of shallow, smoothly rounded contours.

Recesses should also be avoided in designing parts which necessitate melting out the matrix. Where they are specified, in all cases, by making them wider than they are deep will assure satisfactory production. Wall thickness deposited, substantially, is limited to one dimension throughout a part, usually a maximum of ½-inch.

Solid ribs and bosses or heavy sections, therefore, cannot be formed readily. Where a strengthening rib or boss is deemed necessary, these sometimes can be "grown-in", *Fig.* 8, inasmuch as metal can be electroformed permanently or temporarily on a base metal. This process of growing-in can also be applied to composite unit design. The electrically-heated pitotstatic tube shown in cross section in *Fig.* 9 is an excellent example of this method of design. The principal elements—heating spools and copper tubes—are surrounded with a lead mold or matrix formed in the desired shape of the finished tube. On this is electroformed a heavy shell of copper and a surface coat of chromium. When the matrix is melted out the unusual design shown is achieved.

A wide selection of hole sizes can be had ranging from around 0.0007-inch diameter and up. This diameter limitation of 0.0007-inch is dictated by the fact that this is the smallest size of accurate drawn wire now available. Wire, much as a mandrel, is coated with a parting compound and withdrawn from a finished electroform to produce a hole of desired size. Extremely long, small-diameter holes can be easily produced in this way. Small tubing can be utilized in a manner similar to wire. Also, tubing or wire can be grown-in much the same as ribs and

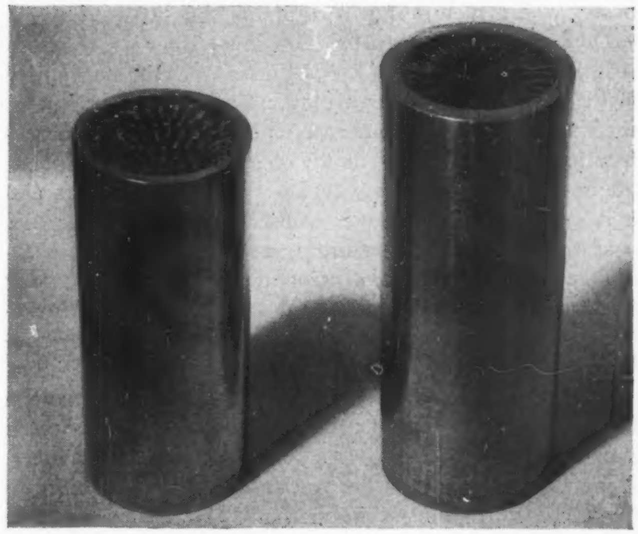
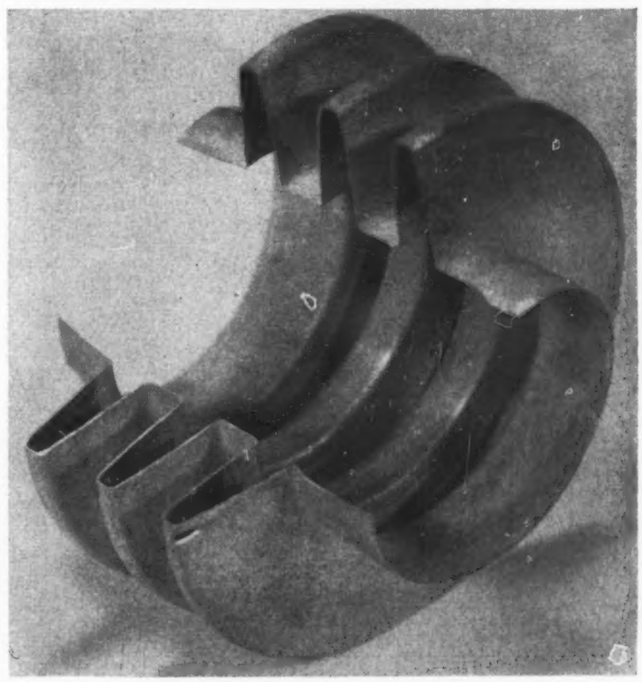
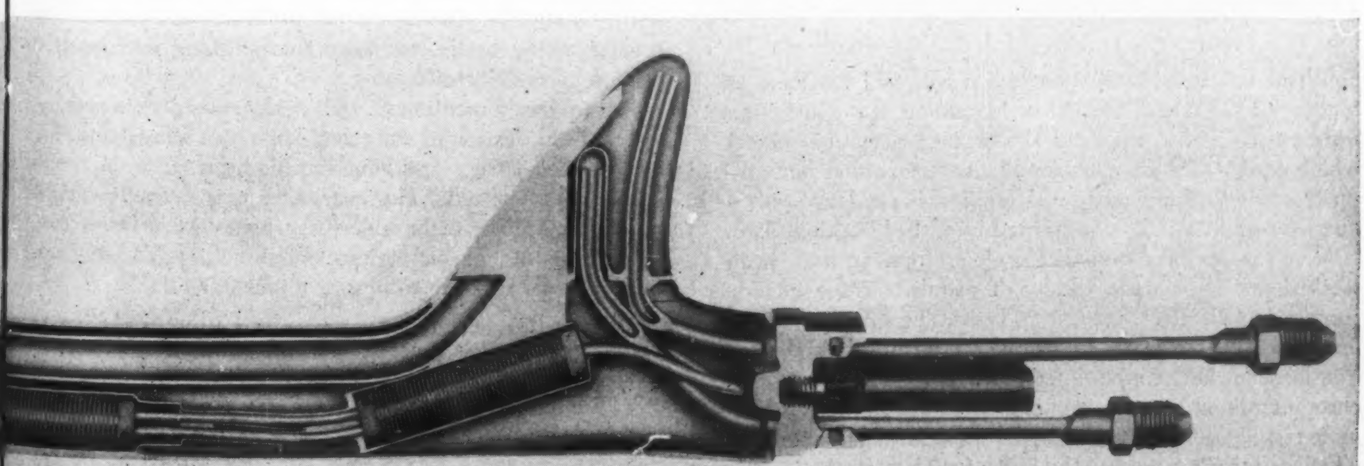


Fig. 10—Above—Electroformed heat exchanger tubes utilizing "grown-in" wires to increase internal surface area

Fig. 11—Below—Exacting internal dimensions are achieved by electroforming this microwave unit bellows





bosses where such design is desirable, *Fig.* 10.

On parts such as the special bellows shown in *Fig.* 11, where ordinary methods of production cannot be applied owing to the depth of convolution, electroforming can be used successfully. In this case where smooth internal surface finish and an exact depth of convolution corresponding to some fraction of a wavelength was required, an aluminum matrix or form was utilized. A special anode is necessary, however, to assure a uniform wall thickness.

Precision gear assemblies which require an exact angular relationship, precision bores and high degree of concentricity often can be produced more economically by electroforming than by any other way, *Fig.* 5. Once a precision master is completed, any number of duplicates may be had. Should a precision gear arrangement or complicated cam require any locating work or jig work before assembly, a precision fixture may be produced also by electroforming. This simplifies the problem of designing for precision assembly in many cases.

Where iron is used, a part may be case hardened to a

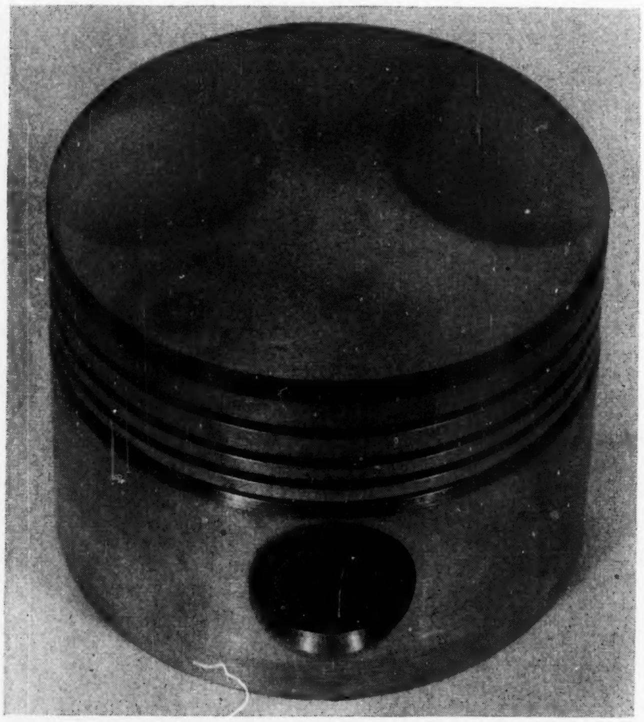


Fig. 12—Aluminum piston for diesel engine with electroformed iron dome, 0.015-inch thick, to resist heat erosion

depth of 0.070 to 0.080-inch and a rockwell hardness as high as 65 C. Heat treating or hardening, however, often results in a loss of much of the original accuracy. Parts which must withstand considerable load can either be built-up extra heavy and machined off flat, backed up with a filler of fusible metal, or supported by a steel backing plate.

Materials: Techniques for electroforming have been worked out for a wide variety of metals. These include copper, nickel, silver, gold, iron, brass, and alloys of cobalt and nickel. Laminated metals such as nickel-lined iron, iron-lined nickel, copper-lined iron, chromium-lined iron, chromium-lined copper, etc., can be utilized. Use of laminated design, however, involves an additional operation which naturally increases the cost of such parts.

Selection of a satisfactory metal or metals should be made on the basis of price, availability, service conditions, physical, metallurgical and electrochemical characteristics. Most commonly used materials are copper and iron and physical design requirements can be relied upon as to which should be used. Where special conditions demand it, a laminate such as chromium or nickel might be used over one of these base metals, *Fig.* 12.

Speed of deposition occasionally can be a deciding factor in material selection. Copper can be deposited at a rate of 0.001 to 0.003-inch in 10 to 20 minutes whereas iron usually is deposited at about 0.001-inch per hour.

Electroformed materials possess metallurgical characteristics similar to metals that have been formed by the more common methods, i.e., rolling, drawing, forging, casting, etc. One major exception exists, however, in that the grain or crystal growth is radial rather than longitudinal. On annealing, the structure returns to conventional grain.

Electroformed iron, as deposited, brinells about 225 to 250, has a tensile strength of about 50,000 to 55,000 psi, and a weight of 0.2842 pounds per cubic inch. Density is extremely high, the electroformed iron actually being less porous than glass.

Tolerances: Extreme dimensional accuracy mentioned previously as one of the outstanding assets of the electroforming process is truly just that. This refers primarily to surface finish and to variation between mass-produced parts. Unlike most processes, variation between parts can be made practically nonexistent by proper control. Dimensional duplication from part to part is easily held within 0.0001 to 0.0002-inch.

Finish Quality Depends Upon Master

Finished surface quality as well as dimensional accuracy of a part is dependent upon the accuracy of the negative metal master matrix, fusible metal, wax or rubber casting, or dissolvable-metal mold. Surface quality of the matrix is reproduced with fidelity even to as fine as 7000 lines per inch. Dimensionally, the steel mandrel or negative metal matrix and the dissolvable metal matrix methods are superior in close-tolerance work. Parts accurate to plus or minus 0.0002-inch with surface finishes around 2 to 5 microinches can be produced.

Owing to the fact that matrices of cast fusible metal, rubber and wax require a master mold, parts produced require somewhat greater tolerances. As a rule on parts so produced, plus or minus 0.001-inch can be held. Surface finish obtainable, likewise, is not quite as good and cost is greater owing to the necessity for polishing each matrix casting before electroforming.

As previously mentioned, wall thicknesses may vary considerably in designs of irregular shape and where this can be tolerated with or without machining, maximum economy can be realized. However, with proper anode design for a specific part, light walls—say up to 0.020-inch—can be held within plus or minus 0.002-inch. Variation in heavier walls may run to plus or minus 0.005-inch.

Collaboration of the following organizations in the preparation of this article is acknowledged with much appreciation:

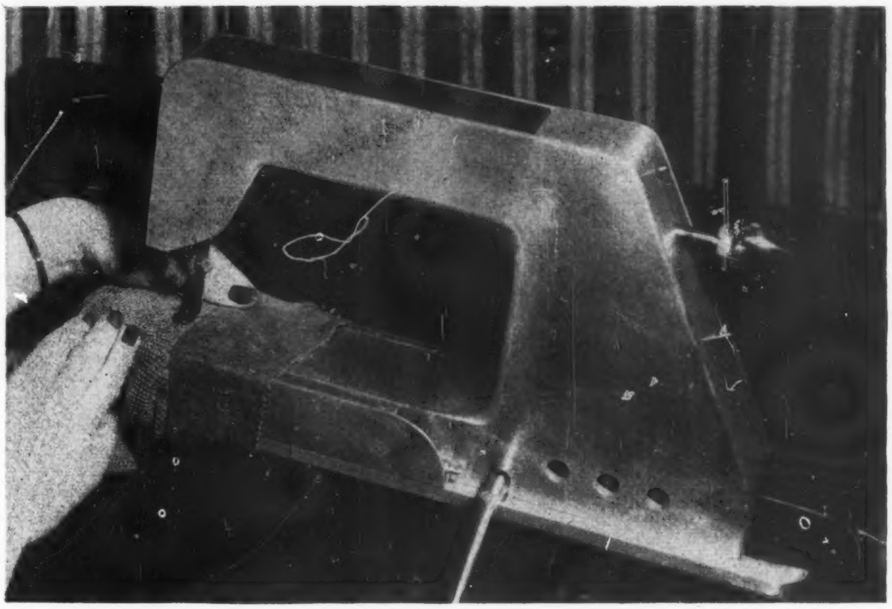
C. G. Conn Ltd. .... Elkhart, Ind.

Kollsman Instrument Division, Square D Co. (*Fig.* 9) .... Elmhurst, N. Y.

Sperry Gyroscope Co., Inc. (*Figs.* 1,2,4,6, & 11) .... Garden City, N. Y.

United States Rubber Co. (*Figs.* 3,7,10, & 12) .... Detroit

Fig. 1 — Right — Representative of modern British design is this aluminum electric sewing machine which weighs only 15 pounds



By Colin Carmichael
Associate Editor, Machine Design

How Britain Approaches Industrial Design

DUE to neglect of the principles of industrial design, many of the consumer goods manufactured in Britain prior to the war seemed old-fashioned and less acceptable by comparison with those of other nations, particularly the U. S. and such European countries as Sweden, Czechoslovakia and Germany. Because of the vital importance of export trade in sufficient volume to make possible the imports of food and raw materials essential to national survival, Britain cannot afford to allow her products to suffer any handicaps in competition with others in the world market.

Realization of the situation has prompted the establishment recently of the Council of Industrial Design under the auspices of the Board of Trade, a government department roughly corresponding to our Department of Commerce. Formed for the purpose of assisting manufacturers and designers to improve the design of their products, particularly consumer goods, the Council has five main functions which may be stated briefly as follows:

1. To encourage and assist in the establishment of "design centers" by industries
2. To provide national displays of well-designed goods by sponsoring or participating in exhibitions
3. To co-operate with education authorities in matters affecting the training of designers
4. To advise with government and other public bodies on the design of articles and equipment to be

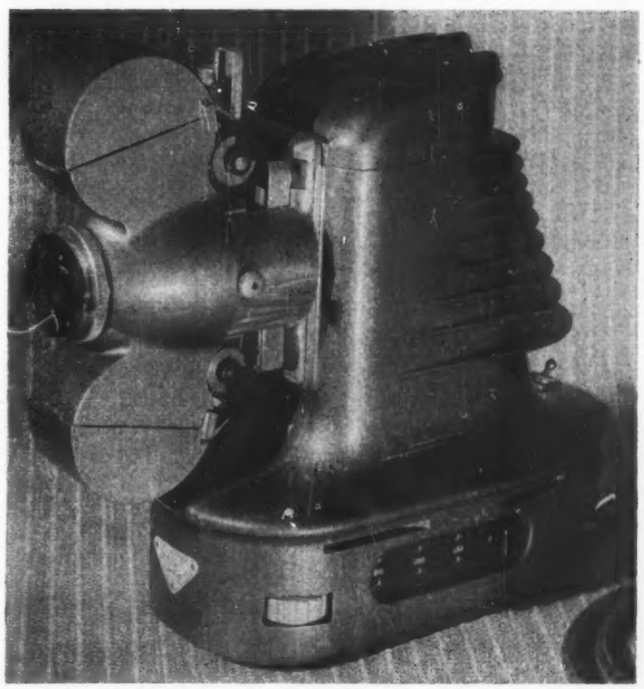


Fig. 2—Another new design is this film-strip projector, a precision optical machine having automatic film feed. It also has adjustable pull down and masks for three different picture heights and requires no tools for servicing

purchased by them for their own use.

5. To be a clearing house for information and advice, both for industry and government, on all matters of industrial art and design.

Design Centers: Broadly speaking, each design center is to be set up to carry out the purposes of the Council as they relate to a particular industry. A primary function is the conduct of research, usually in co-operation with existing scientific or trade associations. Such research includes studies of new materials and their possible adaptation to improvement of processes and products, studies of new processes, and the finding of new outlets for the industry's output.

An important part of this work is the carrying out of consumer research both at home and abroad. The council points out that the design policy of too many firms is apt to be a difficult hit-or-miss affair; through their sales staffs (which may have their own ideas and prejudices) they try to watch the market and the activities of their competitors. Through the design center small firms obtain access to the results of consumer and technical research and a service of

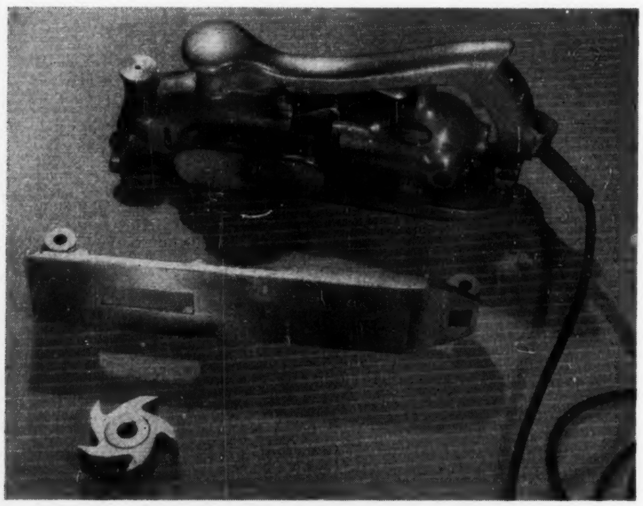


Fig. 3—Portable electric plane, one of the power-driven hand tools shown at the Britain Can Make It exhibition

information from both domestic and foreign sources which would be quite outside their unaided resources.

Financial support for each Design Center is shared by the government and the industry concerned. As an encouragement to industry, annual subscriptions by a company to its design center are recognized as business costs and are exempt from excess profits or income tax. It is expected that, for a center to be fairly representative of the activities and problems of an industry, companies representing at least 40 per cent of the sales turnovers of that industry should subscribe to its center.

Exhibitions: Among the concrete accomplishments of the Council to date is the "Britain Can Make It" exhibition which has been running in London this fall. Though largely concerned with such nonmechanical products as furniture, clothing, pottery, etc., the exhibition also includes equipment and machines such as office machines, phonographs and radios, domestic appliances, scientific instruments, watches and clocks, and transportation equipment. Occupying about 90,000 square feet and with a fixed circulation route about one-third of a mile in length, the display is unique in that the exhibits are not arranged on manufacturers' booths but are grouped according to classification such as, for example, domestic power appliances. In the opinion of this observer, the arrangement gives the entire exhibition an artistic coherence which is lacking in the usual type of heterogeneous commercial exposition.

At the end of the route is a "Designs of the Future" section devoted to new designs—some fanciful, others more practical—such as a space ship, a new taxicab, a yacht that can sail into the wind, a lightweight sewing machine, *Fig.* 1, and a battery-assisted bicycle which stores energy when traveling downhill and releases it on upgrades. The main part of the exhibition, however, is concerned with designs now in production and available for domestic and export markets, *Figs.* 2 and 3.

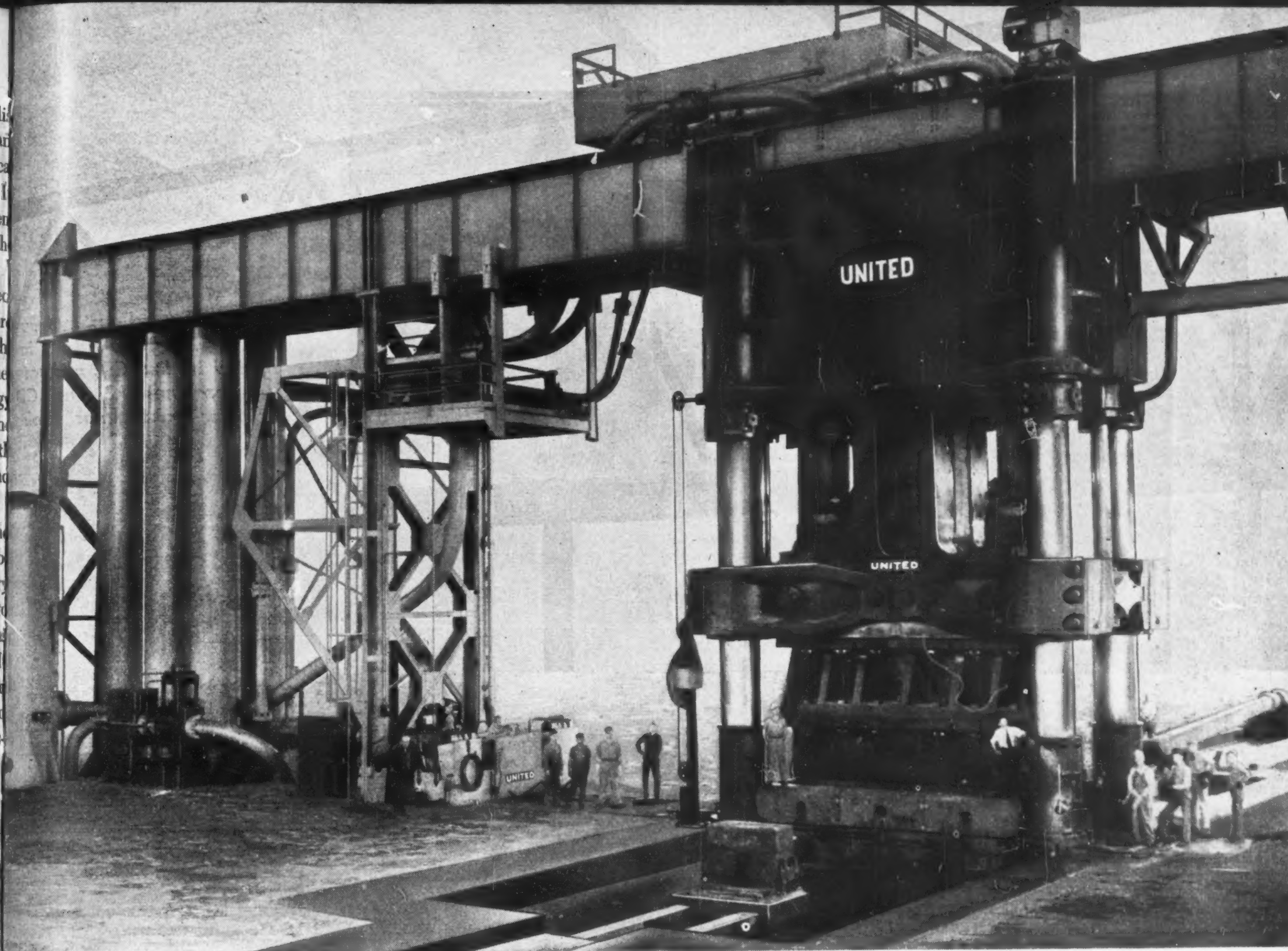
Training of Designers: The Council recognizes the training of the designer as one of the most difficult problems lying within its province, pointing out that industry has failed to realize its needs and to make them clear to the education authorities, while the technical institutions and art schools have failed to co-ordinate their efforts. It is believed that these difficulties can be resolved and an educational program developed which can be extended to include refresher courses and lectures for buyers, salesmen, executives and even production engineers.

Assistance in Evolving Designs

Advice on Design: Although one of the functions of the Council is to advise the purchasing departments of the government concerning design, this is interpreted to mean not merely critical pronouncements upon finished designs but rather consultations with the users and manufacturers during the evolution of designs. Discussions already are under way with several government departments, while the Council is also advising with the British Overseas Airways Corp. on the design of interior equipment for civil aircraft and ground installations.

Information on Design: Fulfilling its mission to spread the gospel concerning design, the Council has issued pamphlets emphasizing the fundamental principles of industrial design and bringing to attention the close interrelation of the four main sections into which the process of mechanized production and mass selling fall. These are described briefly as (a) the preparation of the plan (sketch, design, working drawing, etc.); (b) the exploitation of the production machine; (c) the marketing by the manufacturer; and (d) sale to consumer by retailer.

Industrial design, according to the Council's interpretation, is not simply the plan of a particular product. It is a unity in the industrial process, a controlling idea that owes something to creative design, something to the production machine, something to the consumer, and links them all together. The industrial designer—whether he belongs inside a manufacturing firm or serves it from without—may sometimes act as the captain of a team that includes engineers, draftsmen and salesmen; sometimes he is himself simply a member of the team with a special creative part to play. Either way, the synthesis of visual imagination, production technique and responsiveness to consumer need can be achieved, with the much-hoped for happy results of raising the standard of design and helping industry increase its income both at home and abroad.



High-Capacity Hydraulic Presses

and auxiliary equipment . . . considerations and factors involved in their design

By E. A. Randich*
Mechanical Designer
Bethlehem Steel Co.
Bethlehem, Pa.

HYDRAULIC press design allows such a wide leeway in the selection of parts, design assumptions, and basic methods that preliminary studies may well involve a greater time demand than does the actual design. With this thought in mind, the following article based upon the preferred practice of several manufacturers has been prepared to serve as a guide in determining the machine characteristics.

In designing a press and auxiliary equipment such as is shown in *Fig.* 1, prime consideration must be given to operating pressure. This pressure will be effected by press type, the nature of the process, and the type of accompanying equipment to be used. In general, owing to the limit set upon the size of component parts, the operating

Fig. 1—14,000-ton hydraulic press. Control station is to left of press and the auxiliary equipment at the far left. Courtesy United Engineering and Foundry Co.

* Now with United Engineering and Foundry Co., Pittsburgh.

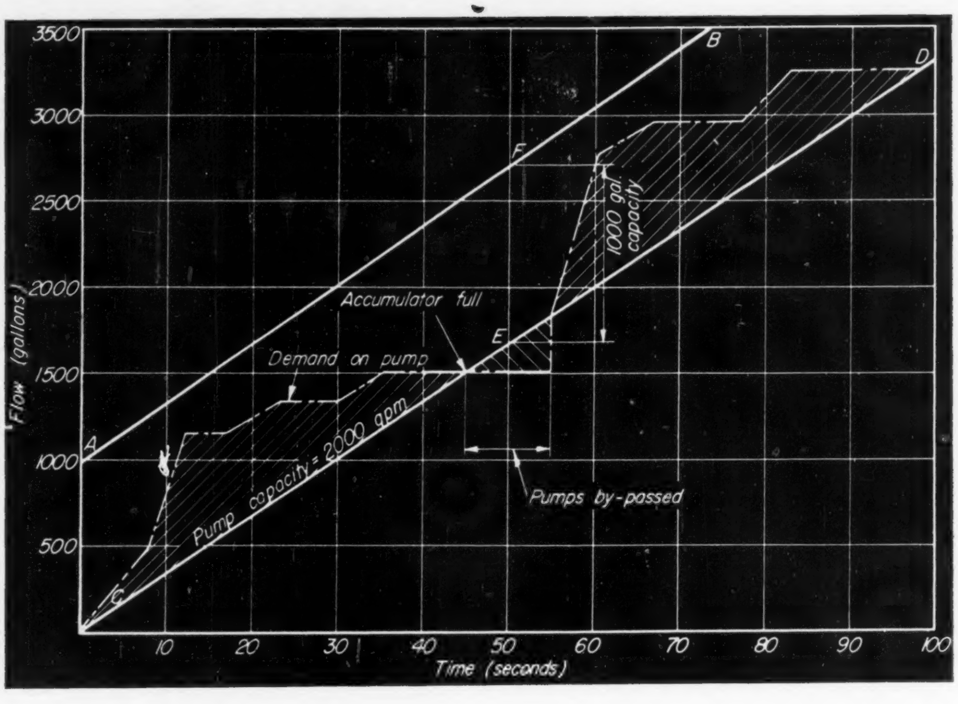


Fig. 2—Demand on hydraulic pump. Delivery rate is indicated by line CD, ordinate between lines AB and CD indicates accumulator stroke

pressures are increased to increase press capacity. To achieve this, higher physical properties are required.

Common pressure ranges, as used in modern industry, can be divided into three groups: Low—250 to 500 psi, medium—1500 to 3000 psi, and high—above 5000 psi. For example, flanging and forming presses usually employ 1000 to 2000 psi. Piercing and deep drawing presses are in the 2500 psi class. Car wheel forging and armor plate bending and straightening presses are in the high pressure class and may run up to 12,000 psi working pressure. The general forging type of press, however, utilizes 3000 to 4000 psi.

At the present time, with the growth of the plastics and plastics molding industry, there are a large number of presses which range from an operating pressure of 250 to 3000 psi. These ranges have been more or less established due to the fact that size, capacity, stresses, and cost are all factors which depend upon the job to be done and the simplest way of doing it. Thus it has been possible to build up definite ideas as to capacities and pressures to be used in designing presses for certain functions.

There are certain criteria which should be followed in determining equipment to be used. For example, it has been found good practice to reduce the working pressure as much as possible in order to keep down the bulk of the press, to reduce the size of the valves and piping, and to minimize operating failures and leaks of all kinds. Generally a lower line pressure is used, and this pressure is then intensified to a higher pressure when needed. With an intensified system the high presures are confined to the press cylinder and to the pipe line connecting the intensifier to the cylinder. This practice obviously minimizes operations difficulties. A prefill valve may be used in such a system with the valve mounted in the head of the press and a gravity feed tank mounted on top of the press head. The prefill valve also serves another purpose in eliminating water-hammer effects which are present in high pressure accumulator systems. With a properly designed prefill valve, vacuum cannot be created and hence the usual surges found in the accumulator are eliminated.

Pump Systems: The pump and accumulator capacities must be selected to suit the requirements of the hydraulic unit. This is usually done by estimating the actual condition through an analysis of comparable units previously designed. Shown in *Fig.* 2, is a graph showing typical pump demand in gallons, plotted against time in seconds. The line *CD* represents pump delivery, and areas above this line represent demand in excess of the pump delivery. The area below the line represents pump delivery in excess of the demand. It can be seen that the pump delivery must be greater than the average delivery required at all times. Also, the accumulator capacity must be greater than the peak area above the pump delivery line. Also shown in *Fig.* 2, is the amount of hydraulic fluid used. The accumulator capacity is the height of the ordinate between the lines *AB* and *CD*, thus *EF* represents the accumulator stroke. The ordinate between *AB* and the pump demand curve represents the distance of the accumulator from the bottom of its stroke. When the demand curve falls below the pump delivery line *CD*, the accumulator is full and is at the top of its stroke. At this point the pumps are by-passed and do not deliver to the press until the demand curve crosses the line *CD* once more. When the demand curve rises to *AB*, the accumulator is at the lowest point of its stroke, and the full capacity of the pump would be necessary to meet the press demand. *Fig.* 3, shows the relation of the accumulator stroke to time in seconds.

The amount of fluid to be used and the rate of the demand in a single system can be determined from the press cylinder displacement and the estimated time for a complete press stroke. By estimating the number of gallons demanded for a definite period of time, and then estimating the press-idle time, the pump capacity required may be determined closely. Accumulator capacity is then determined from the fact that it must supply the difference between the press demand and the pump delivery.

Pumps: For high pressure work, pumps are generally of the reciprocating plunger type with crankshaft and flywheel, or of the more modern centrifugal type. They may

be motor or steam driven, depending on available power. Duplex or triplex pumps may be used, especially in smaller units. Inasmuch as hydraulic pumps for this type of application are constant-speed uniform-load machines, capable of being started without a load, they are well adapted to synchronous motor drive. Because synchronous motors can be used to a great advantage in improving the electrical power factor, pumps should be driven by synchronous motors whenever lagging loads are encountered.

VALVING: The pump usually is controlled by means of a by-pass valve which opens when the pump load is relieved and returns the pump delivery back to the sump tank. When this valve is open, fluid is circulated through the pump and back to the suction side without a build up of pressure. When the valve is closed, the delivery is directed into the press or to the accumulator line. When using accumulators, the by-pass valve is actuated by the accumulator through electrical means in most all cases. When the accumulator is almost empty, and naturally at the lowest point of its stroke, the by-pass valve is closed, and the pump then delivers to the accumulator until enough fluid has been pumped into the accumulator to raise it to the top position of its stroke. At this point the accumulator opens the by-pass valve and the pump again delivers fluid to the sump tank for future recirculation. The pump then remains in the unloaded state until the supply in the accumulator is exhausted and the by-pass valve is closed and allows the pump to operate once more.

ACCUMULATORS: A hydraulic accumulator consists of a long-stroke single-acting plunger working in a hydraulic cylinder. It is so loaded that when the fluid is pumped in against the load, energy can be stored in the accumulator and given up later when operating valves are opened. The simplest and most common accumulator is the weight-loaded type. In this design, the plunger is provided with a yoke to which suspension rods are attached. These rods carry a holder and an open tank filled with some sort of ballast. In many cases, however, segmented plates are used instead of the ballast tank.

The total load required, including the weight of the moving parts of the accumulator, is equal to the pressure times the plunger area, and the total energy stored in foot-pounds is equal to the total load in pounds multiplied by the stroke of the accumulator in feet. This, of course, can be expressed easily in horsepower. For example, a 30-in. diameter accumulator with a 20-ft stroke loaded for 3500 psi pressure carries a total load of 2,500,000 lb, and will store 50,000,000 ft-lb or 90,000 hp-sec of energy. Now, supposing that this amount of energy is given up in 12 sec, then 7,500 hp will be developed for the short length of time the accumulator is dropping. This rate is taken to be 1.67 ft per second as a typical value. The rapidly dropping weights develop a kinetic energy which must be given up when they are stopped. The effect of this sudden stoppage, when the press operating valve is closed, is to build up a pressure surge in the entire system. This is the well known water hammer effect. Now a 30-in. diameter accumulator dropping at the rate of 1.67 ft per sec will develop a kinetic energy of 108,000 ft-lb where kinetic energy $= \frac{1}{2} MV^2 = [2{,}500{,}000\ (1.67)^2]/(2 \times 32.2)$ and if, as is commonly the case, the motion is retarded in 1½ in. it will develop a pressure of 1,220 psi in the system. This excess pressure supplies the force of retardation which gradually brings the accumulator to rest, and may in many cases be more than the system can safely resist. Thus connecting piping must be designed carefully to take care of such shocks and overloads.

The excess pressure can be kept within reasonable limits by several methods. As a typical case, a dropping speed of 1.67 ft per sec corresponds to a water delivery of 3,660 gpm., since

$$Q = \frac{AV}{t} = \frac{\pi}{4} \times 30^2 \frac{20 \times 12}{\frac{1}{5}} = 847{,}000 \text{ cu in./min.}$$

and

$$\frac{Q}{231} = \frac{847{,}000}{231} = 3660 \text{ gpm}$$

where Q = quantity in cubic inches per minute, A = area in square inches, V = velocity in inches per minute, and t = time in minutes. Thus the water demand of the press must be low enough in relation to the accumulator volume

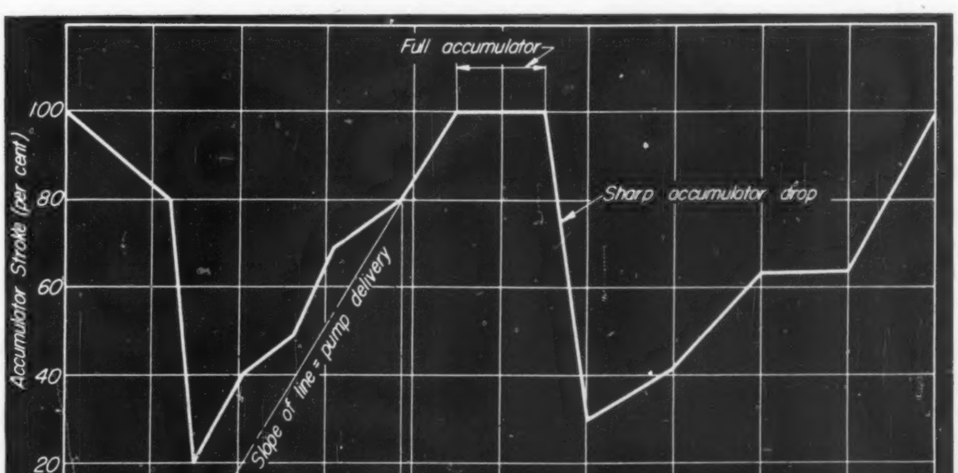


Fig. 3—Accumulator position plotted against time and pump demand plotted. Slow fluid accumulation and rapid discharge will be noted

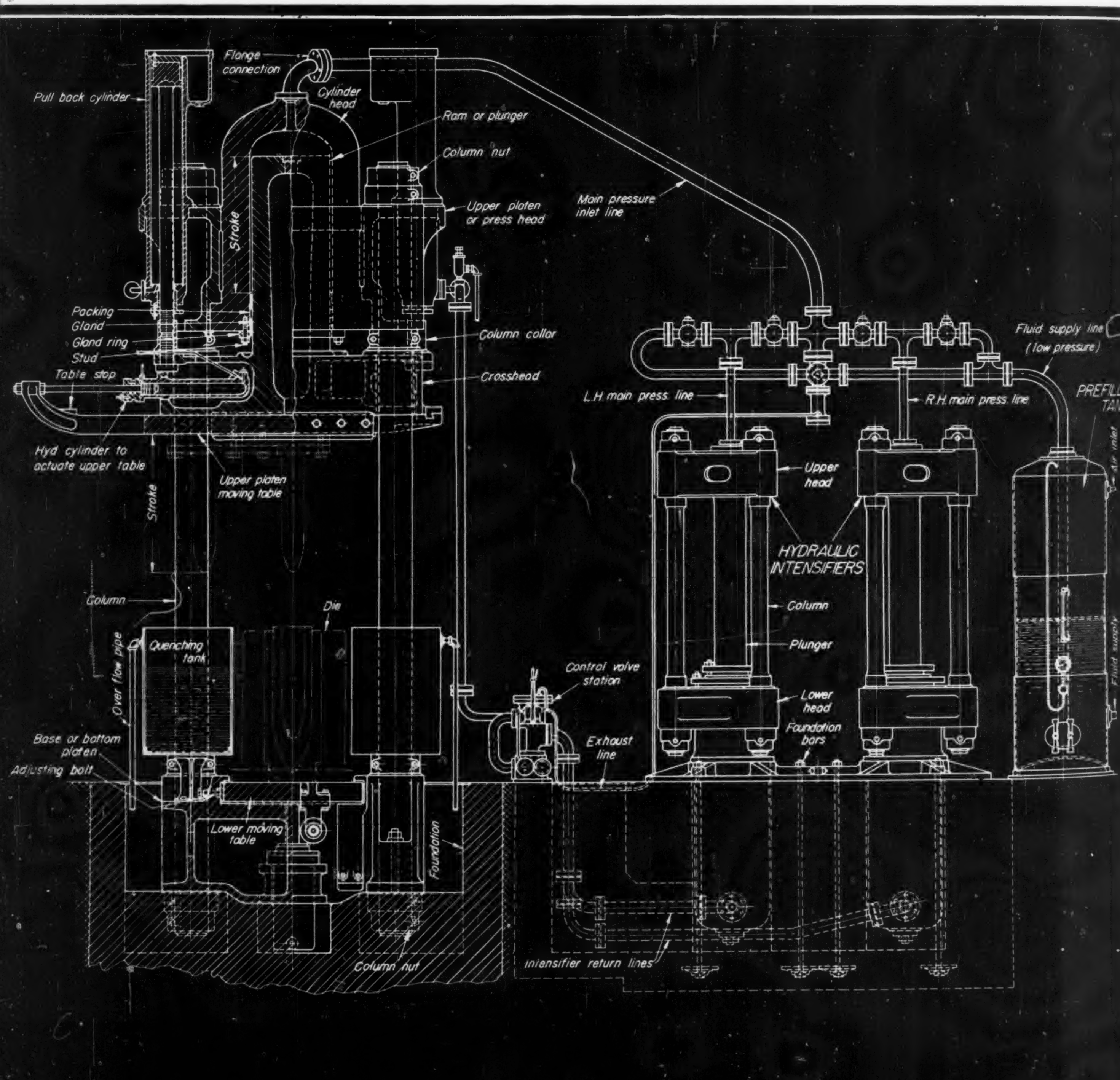
so that the dropping velocity does not become excessive.

A common method used to remedy this condition is to provide loaded shock absorbers in the line. However these are only partially effective, due to their small capacity. The best method in use today is to make the accumulator itself serve as a huge shock absorber by suspending the weights on groups of coiled springs placed around the suspension rods. The springs must be designed with sufficient load capacity to carry the entire accumulator load and still have additional deflectional capacity before they are totally compressed. Spring suspension is not necessary if all other precautions are taken, but this cannot be relied upon, especially in operation when workmen are liable to lose control, or an accident of some sort take place. If pressure-loaded accumulators are employed with compressed air being used as the medium, as is sometimes the case when advantage of the light weight of the moving parts is taken into consideration in the design, the inertia will be a minimum and hence the shock load can be reduced. An unfortunate disadvantage is its high operational costs.

INTENSIFIERS: If at all possible, it is better to use a low line pressure and then intensify to a higher working pressure. This may be done with a hydraulic intensifier which consists of two cylinders of different diameters, with a plunger of two different diameters, one working in each cylinder. Low pressure fluid enters the larger cylinder and the pressure is then raised in proportion to the inverse ratio of the respective diameters, the volume of the high-pressure cylinder being decreased in direct proportion to the inverse ratio of the diameters.

As a rule the low pressure end of the intensifier is under valve control, the high pressure end discharging directly into the press cylinder as may be seen from *Figs.* 4 and 5. In order to keep the intensified or high-pressure fluid out of the low pressure line, if the prefiller pressure is also admitted to the press cylinder, a check valve must be used. This type of system is used today in preference to accumu-

Fig. 4—Elevation of 3000 ton hydraulic piercing press such as is illustrated in Fig. 1, showing relative position and size of components as well as piping



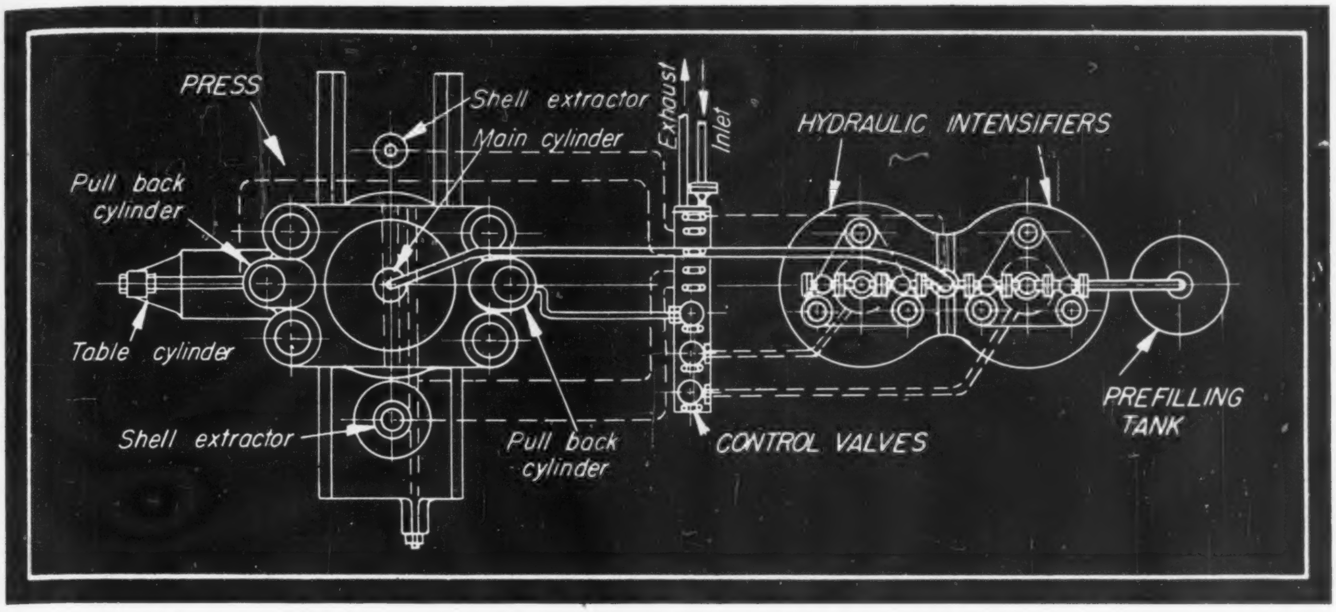


Fig. 5—Plan view of piercing press of Fig. 4 showing location of pull-back cylinders, and relation of parts

lator systems owing mainly to the high pressures attainable and to the much smaller space needed for the intensifier, and also to the fact that the entire system is much simpler from a design and operation standpoint.

Structure: Due to the fact that, as a rule, maximum loads are definitely known, safe working stresses can be higher than those used in most machinery of the heavy type. Because of the large forces encountered, the designer must employ the best materials available for castings and forgings and use all the facilities at his disposal to make a strong, compact, sound and inexpensive design. Cast iron is little used for main parts, structural shapes are seldom utilized, and rolled steel sections and weldments are used to only a very limited extent. Cast steel, and forged steel are the principal structural materials used in hydraulic press work. This is because of the heavy metal sections employed and of the grade of materials and workmanship required.

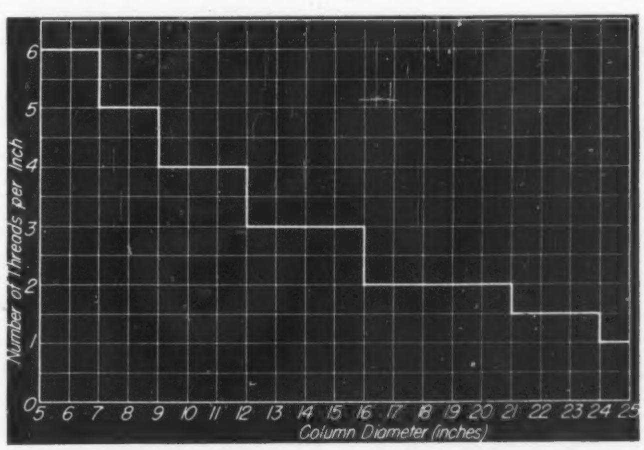
Press platens for large presses are generally steel castings made in the shape of a heavy box or I-beam section. These are designed as beams in accordance with the rules of flexure, for both total bending moment and distributed loading due to the press cylinder pressure. These loads cause a deflection in the top platen and hence the maximum deflection must be calculated to determine the section modulus necessary to keep the deflection within the allowable amount. Platens of boxed sections are ribbed so that the stresses are carried away without abrupt directional changes from the point where the load occurs to the supporting columns. Ribbing should be accurately placed so that there be no danger of local stress concentrations, causing breakage between the ribs.

Column and column nuts should be well proportioned and should be sound material. They are generally steel forgings and castings, respectively. Column nuts are of the split-nut type with bolts to force the nuts securely against the column threads. In determining the column sizes, the total load capacity of the press is divided by the number of columns and the resulting load is used as the load that causes a certain stress in the column which is calculated as a direct tension member. However, this is true only if the load acts directly in the center of the press and thus distributes the load equally among the press columns. Should the load shift to one side at any time, the loading becomes eccentric and the columns do not share the load equally, but the column nearest the load will take more than its share of the loading. The effect of this eccentricity is to cause a bending moment on the columns and thus impose an additional stress on the columns in conjunction with the direct tension stress.

Since presses take the load in one direction only, the column threads should be of the buttress or acme type with the pitch in direct proportion to the column diameter. *Fig.* 6 shows the proportions of thread pitches used for different sized columns. These are average figures of one manufacturer and may vary with different manufacturers.

Columns: A most important factor is to use the full column strength and to keep the column nuts snug. A press column varies very little in diameter along its entire length, hence when it is in service the stress is practically the same throughout its length. So it has been a common practice to hold the press platens between the outer two column nuts, and the inner two clamping nuts. Generally

Fig. 6—Proportion of screw threads advised for use with press columns and nuts, as influenced by column size



the outer nuts are set up as tightly as possible while the press entablature is resting against the inner nuts. At the same time steam is injected into the column, by securing a steam hose to the column. This heats the column and causes elongations to occur. The nuts are then drawn up snugly. As the columns are allowed to cool, they shrink, this causes a pull on the nut threads and makes the fit much snugger than it would be by plain manual tightening. When pressure is placed on the press cylinder the columns are elongated and the inner nuts are tightened with the columns initially in tension. This means that as a working load comes on the press the nuts will be snug and will not loosen due to the initial prestressing and elongation. In heating the column to the point where the column takes a permanent set, it is possible to exceed the elastic limit and thus it can be seen that the process may be dangerous unless it is administered carefully and according to set procedure. The initial tension placed upon the column depends on the temperature differential between the column and surrounding metal.

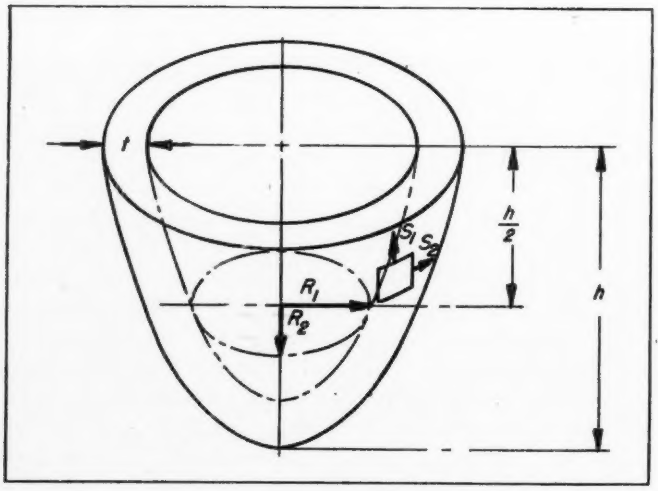


Fig. 7—Schematic of cylinder head for purpose of determining stresses. Represented is any figure of rotation

CYLINDERS: Press cylinders must be designed to withstand the hydraulic working load which produces a tangential stress tending to burst the cylinder, and a radial stress causing compression on the inner surface of the cylinder. The thin cylinder formula can be used in some cases where the wall thickness is small compared to the cylinder diameter. But in most cases the thick cylinder formula must be applied. This is due to the fact that the stress varies from a maximum at the inner surface to a minimum at the outer surface of the cylinder. Of the number of formulas in use today, all are an adaptation of the basic Lame formula:

$$p=S\left(\frac{r_2^2-r_1^2}{r_1^2+r_2^2}\right)$$

where p = pressure psi, S = working stress psi, r_1 = internal radius inches, and r_2 = external radius inches. One of the common adaptations is that known as the Tachap-pot-Lame formula which consists of the Lame formula multiplied by the constant 1.5.

The place of greatest weakness in the cylinder appears to be the head on the closed end portion at the junction formed by the closed end and the cylinder wall. Here the cylinder must be carefully shaped due to the inherent weaknesses of corners. The curvature of the head should be not more than ¾ of the cylinder diameter, and the radius connecting the head and sides of the cylinder should be made as large as feasible. The spherical head is of course the strongest head that can be made, hence many presses have cylinders with spherical or domed heads.

Usually the head thickness is made 1/3 to 1/2 greater than the thickness of the cylinder walls. The head thickness can be determined by assuming it to be a hemispheroid plate, supported all around its periphery and loaded with a distributed load. Common formulas, applicable to any figure of rotation, used to determine head thickness are:

$$S_1=\frac{pR_2}{2t}$$

and,

$$S_2=\frac{pR_2}{2t}\left(2-\frac{R_2}{R_1}\right)$$

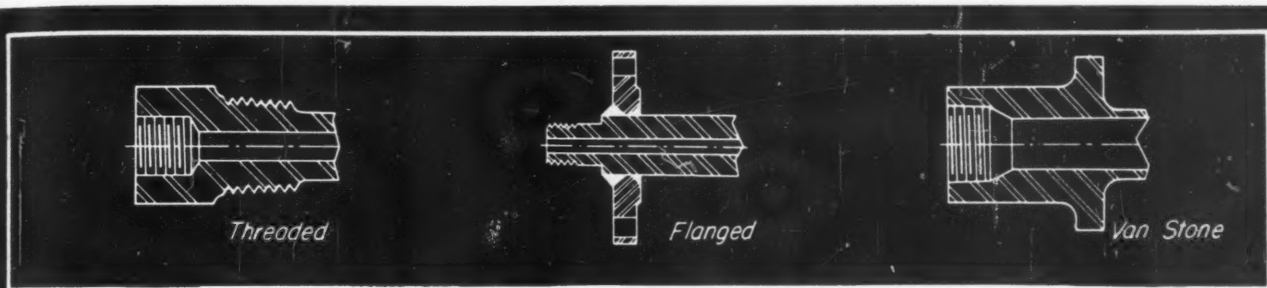
where, referring to *Fig.* 7, R are mean values, p is the internal pressure in psi, S_1 is the meridianal stress in psi, and S_2 is hoop stress in psi.

Longitudinal stress in a cylinder does not appear to be a factor requiring deep consideration, inasmuch as the longitudinal stress is only half as much as the lateral stress. The longitudinal force against the platen is taken on a shoulder at the open end of the cylinder, or it is taken on a shoulder built into the upper platen at the top of the cylinder. The shoulder should be designed with proportions so that the bearing stresses will be well within allowable limits.

It is best to keep all bending stresses from being produced in the cylinder. Thus greatly reducing the stress sustained by the cylinder and keeping the desired wall thickness as small as possible. It is good practice to keep all projections away from the cylinder and let it serve one purpose only, the transmission of hydraulic pressure from the inlet port to the work area between the press platens. It is also good design to outside pack the cylinders so as to greatly reduce the labor required when repacking becomes necessary. Inside packed cylinders make it difficult to locate and service packing.

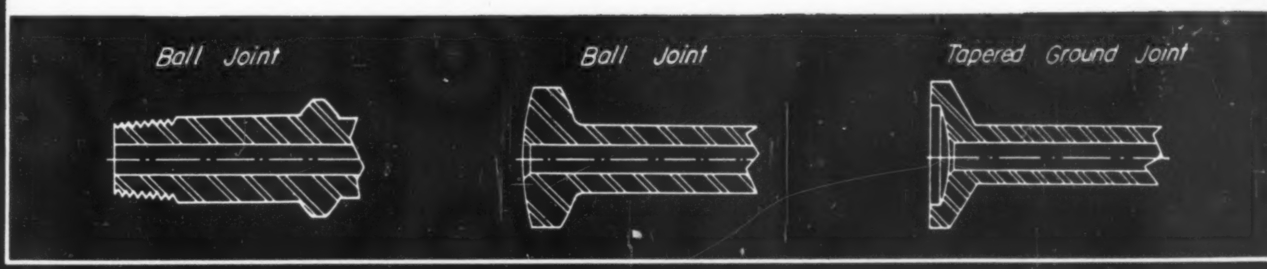
Hydraulic cylinders can be placed above on the press upper platen, or below on the lower platen, where they are known as push-back cylinders. When head room permits they are placed above the work area and are used as pull-back cylinders. However the push-back type does away with suspension rods and permits much more head room. The pull-back cylinders are controlled by pilot-operated valves with a check valve operated by a hydraulic cylinder. The lifting and lowering stroke of the press is controlled by a pilot valve which also controls the pull-back valves and the check valve.

Another system in use today is to have a low controlled pressure in the pull-backs, lowering of the press platen is then accomplished by admitting low pressure fluid through a three-way valve into the main press cylinder. Thus, the main cylinder is filled from the low-pressure line and no prefill tank is necessary.



Basic Design of Thermowells

By George R. Feeley
Trinity Equipment & Supply Co.
New York, N. Y.



DESIGNERS often are confronted with the problem of applying thermometers or thermocouples in machines. This paper presented at the recent Instrument Society Conference, discusses standardized thermowells to assist in eliminating unnecessary fabrication costs and production problems involved with unorthodox and sometimes needlessly complicated designs

MEASUREMENT and control of temperature in almost all phases of industry has become a matter of increasing importance in recent years. The development of highly complex processes, and the utilization of constantly increasing pressures and higher temperatures have made necessary many advancements in the field of thermal instruments. Thermowells are an important part of most temperature instrument installations, and their design as well as the choice of material from which they are to be made consequently deserve serious consideration.

A thermowell is that piece of equipment which makes it possible to insert the sensitive element of a temperature-measuring or controlling instrument into a critical process area. This area may be a pipe, a vessel, a furnace, or any enclosure in which the sensitive element requires protection from the process medium. Because of their function, thermowells are made of a wide variety of materials to withstand a correspondingly wide variety of conditions, and are of many different designs for different types of equipment. While some installations require wells made of ceramic or other heat-resistant material, most wells used in industrial process work are made of metal and it is this type which will be discussed with reference to the basic requirements of a good thermowell, the different types of wells and how they are made, and, the type best suited to particular design requirements.

Fig. 1—Top—Basic methods for installing thermowells, including pipe thread, flanged and ground joints

BUILT-UP WELLS: As the name implies, these consist of a piece of pipe or tubing which usually has one end closed by welding or spinning, or a combination of both. In many installations, the well is used in this condition by welding it into place. Known as protecting tubes, these are the simplest form of well. When conditions make it

necessary to remove the well for periodic inspection, a joint is provided near the open end as a means of making the well pressure tight. This joint can be either threaded, flanged, or ground, and is held in place by one of several types of fittings, *Fig.* 1.

Built-up wells are satisfactory in many instances and are widely used because of their low cost and ease of fabrication. They also have the advantage of permitting the manufacture of wells in almost unlimited length. Built-up wells, however, have several disadvantages in that they require the use of material available in tubing form and sizes which are standard. This is particularly troublesome when using bulb type instruments where proper fit between the bulb and well is essential for proper operation. Proper fit eliminating the conduction of heat or cold through the dead air space between the inside wall of the well and the bulb is undoubtedly the most favorable condition for bulb type installations.

Welded Joints Should be Avoided

Another disadvantage is the possibility of failure as a result of welding. This is particularly troublesome in chrome-nickel stainless steels when unstabilized material is used and the finished well is not properly stress relieved. Carbide precipitation is the result and because of this, the material tends to lose its corrosion resistance. As it is very difficult to insure proper stress relieving, welded joints in thermowells, particularly when used for severe service, should be avoided whenever possible.

SOLID DRILLED WELLS: A second type, the solid drilled well, while limited in length to 6 feet, is the best from the standpoint of safety, accuracy, and flexibility of design. Made by drilling bar stock, a forging or a casting and then machining the outside to the required size and shape, welding and heat treating are eliminated. Wall thickness can be made as heavy or as thin as the installation requires and any material that can be machined can be used. It is possible to locate the position of the hole, often feared to be inaccurate, within a tolerance of 0.001-inch. While it is possible to hold to this tolerance, generally it is not practical to do so as it takes too long to do the external machining. A practical allowable tolerance on concentricity of bore is 10 per cent of the wall thickness.

Use of solid drilled wells is recommended whenever possible. Often it is possible to use a combination of built-up and solid drilled construction by making the critical part of the well of solid bar and welding this to pipe or tubing for extension of length through heavy insulating walls or similar construction requiring length of well which is not exposed to extreme service conditions. Combination built-up wells are suitable for many services but should be avoided wherever failure of the well might cause a costly shut-down or a serious injury to operating personnel.

Three basic points to be considered in designing a thermowell are: (1) Type of instrument with which it is to be used; (2) the type of equipment on which it is to be installed; and (3) the service under which it will be required to operate. The type of instrument with which a well is to be used will determine one of the basic points of well design, that is, the internal diameter. Bulb type instruments require close fit between the inside diameter of the well and the bulb while thermocouples do not require a close tolerance on the bore because of the difference in the measuring principle involved.

To be considered next is the type of equipment into which the well is to be inserted. This is necessary because it will determine, in most cases, the means which must be used to join the well to the equipment. Four basic means of accomplishing this are: Taper pipe thread (most common), flanged, ground, and welded joints.

Length of Well Important

The third problem that must be considered is the service under which the well must operate. Temperature, pressure, speed of flow, corrosion, erosion, etc., must be taken into consideration to determine how sturdy the well should be. Having decided this, the wall thickness of the well and its external shape can be determined. Most thermowell designs are made leaving the length of the well as a variable so that the design can be used under varying conditions. It is, of course, necessary that the well be of sufficient length to enable the temperature element to be inserted far enough into the process fluid to insure proper readings.

After the basic points of design have been determined, several questions will arise concerning the points of lesser importance, such as: Should the closed end of the well be squared or round; should the well portion below the joint be

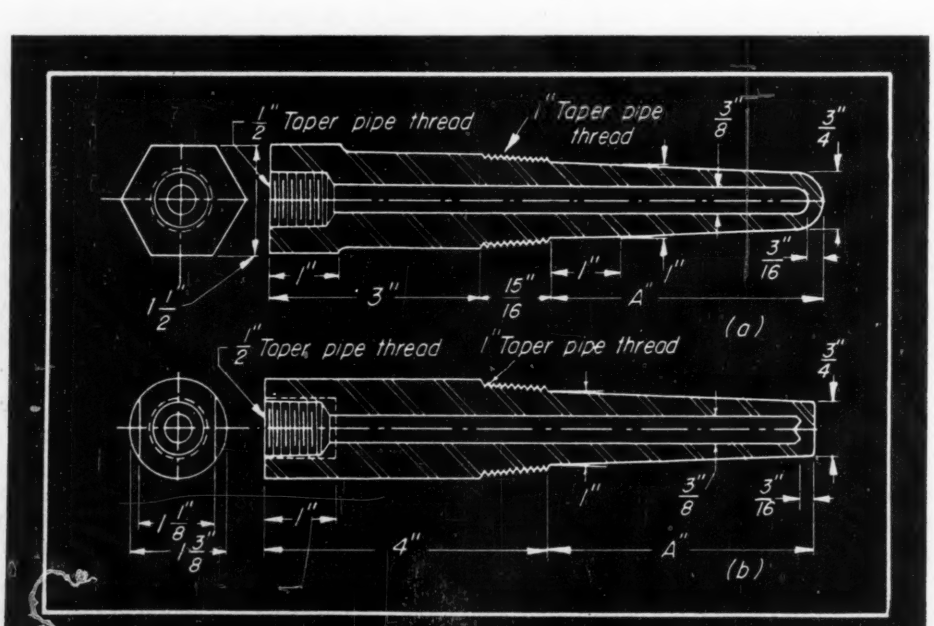
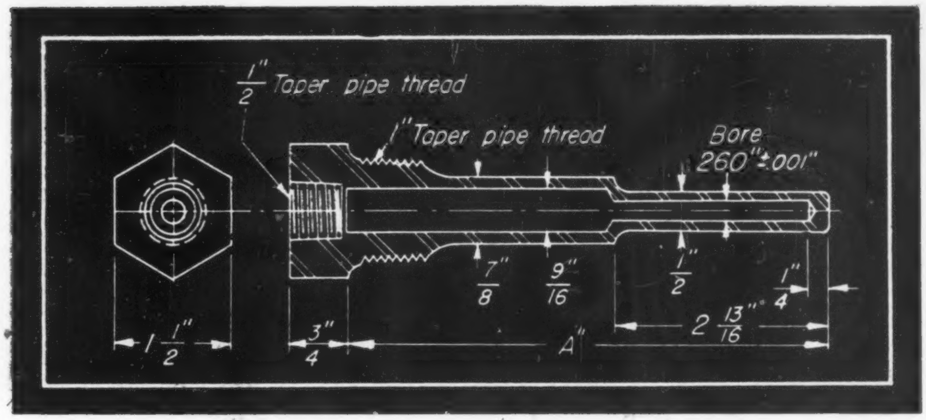
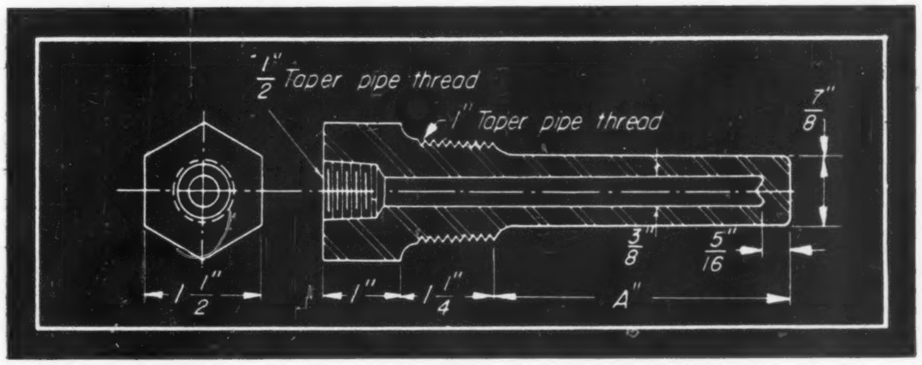


Fig. 2 — Left — Although almost identical, well (a) costs over 25 per cent more than the well shown at (b)

Fig. 3 — Right Top — Designed specifically for bimetal thermometer installation, this design indicates advantage of solid construction in eliminating dead air space at the bulb

Fig. 4—Right Below—Design for a good general-purpose well in which fabrication costs have been cut to a minimum





straight or tapered; what should be the shape of the bottom of the hole; if a threaded joint is used, what size threads would be best, etc. While these factors usually have little effect on the proper operation of the instrument, they often have a great effect on the cost of the well. Two similar well designs, *Fig.* 2, appear to be almost identical, but there is a difference in fabrication cost of more than 25 per cent between the two. As neither well has any particular advantage over the other from the standpoint of service, it seems logical to try to eliminate this extra cost.

Thermowell shown at (a), *Fig.* 2, has several design features which needlessly increase the cost. Extra machine operations are required to shape the end of the well and the bottom of the hole. A close examination of the taper tion below the threads shows that there are two tapers; one extending from the threads to a point 1-inch below, and the second from that point to the end. Two machine setups are necessary and a substantial amount of time is required to blend the two tapers together to provide a smooth finish. Also, the fact that hexagon material is used increases the poundage of the bar stock used. On short wells use of round bar stock, however, does not offer a saving as the cost of milling wrench flats tends to offset the difference in material cost. It does cut the cost of longer wells, however, and also often tends to improve delivery of steel bar stock because rounds generally are more readily available than hexagons.

The well (b), *Fig.* 2, has all of these features eliminated. The bar stock used is 1⅜-inch diameter round instead of hexagon, the hole is left as drilled, the end is cut off square which eliminates the extra forming operation, and the portion below the threads is cut on a straight taper.

A well designed for use with a bimetal thermometer, *Fig.* 3, is included particularly to illustrate the advantage of solid drilled wells to eliminate unnecessary dead air space between sensitive element and socket wall. General practice on this type of well is to ream the hole 0.010-inch larger than the bulb diameter to a tolerance of plus or minus 0.001-inch. This allows sufficient clearance to prevent binding and at the same time cuts down the insulating effect of air space to a minimum. Holding this tolerance costs money and the hole is enlarged above the sensitive area to facilitate machine work.

A simple design of a good general-purpose well is shown in *Fig.* 4. Machine operations are cut to an absolute minimum and below the threads the well is straight, which avoids a costly tapering operation.

Servicing Factor Must be Considered

The threaded joint illustrated in *Fig.* 1 is most commonly used. Many wells, however, must be removed at frequent intervals for inspection. Threads tend to distort under frequent tightening and it is recommended that a flanged joint be used if this is necessary. Of the several flanged variations which deserve consideration, the most common is the type made by drilling a blind flange to fit the well and then welding the two as shown. If welding is not advisable, the Van Stone flange shown in the upper right-hand corner can be used. On severe service applications, it often is necessary to eliminate the use of gaskets and in such cases a ground joint should be used. The ground taper-joint is seldom used owing to increased cost over the ground ball-joint types. Although ground-joint wells usually are no more expensive than threaded wells, their installation is more costly because of the rather elaborate fitting into which they must be inserted.

Application of these simple points of thermowell design should enable most designers to cut the cost of thermowell requirements by a substantial amount. Selection of the right well for the job should bring about a further saving by reducing the high cost of thermowell failure and frequent replacement.

Mechanical Seals

By Douglas R. Lewis
Mechanical Engineer
Newark, N. J.

Part IV—Theoretical Design

TO DESCRIBE a seal as "working perfectly" is to be guilty of a contradiction in terms, work being the production of motion or, in this case, heat. Sealing perfection, in other words, is approached only when the heat generated by the sliding friction of the faces approaches zero. If the seal is working, that is, generating heat, it cannot be perfect, although for practical purposes it may be entirely satisfactory. The reason for this is not difficult to understand when one considers that the factors which cause heat are the same factors that limit the life of the seal slowly by normal wear or abruptly by galling or seizure. Assuming that the faces are in continuous, overall, intimate contact, the life of a seal is inversely proportional to the heat it generates. If it generated no heat it would never wear out. It becomes of first importance, therefore, to relate the heat-producing factors and to see how they can be controlled to minimize wear.

Calculations based on the following equation agree with observed data. It is derived mainly from the standard equation for thrust bearings. Because of the difficulty of measuring the heat directly it is written for absorbed horsepower, making the check against observed results easy with a dynamometer or similar instrument.

$$hp = \frac{5.289 \times 10^{-6} nfL(D^3 - d^3)}{D^2 - d^2}$$

where n = angular velocity in revolutions per minute, f = coefficient of friction, L = total face load in pounds, D = outside diameter of contact area in inches, and d = inside diameter of contact area in inches.

Magnitudes of all these factors except angular velocity are within the control of the seal designer. In the curves presented, to help visualize their relationships, the quantity $(D-d)/2$ is the radial width of the contact area, or face width. The quantity $d-0.0625$ is the shaft diameter, allowing a radial clearance of 1/32-inch between the stationary sealing face and the shaft. When the horsepower is plotted as a function of shaft diameter, power is still being absorbed when the shaft diameter is reduced to zero. This is not illogical, because when there is no shaft the quantity d alone becomes zero, which does not operate to reduce the product of the remaining factors. One might

Fig. 30—Extreme Left—Rotating surface worn in to stationary surface in Fig. 31. Continuous annular corrugations indicate wear but not scoring

Fig. 31—Left—Stationary surface worn in to rotating surface in Fig. 30. Dull, ragged patches indicate galling due to lubrication failure

Fig. 32—Right Below—Four surfaces with same microinch scratch depth but with different flat area percentages

think of this condition as a disk with no hole in the center.

Plot of horsepower against face width also shows power being absorbed when the face width is zero. This can be explained by the fact that the quantity $(D^3-d^3)/(D^2-d^2)$ is actually the limit of the sum of the products of the differential, or elementary, areas and their distances from the axis of rotation. The integration is somewhat like that used for calculating the moment of inertia of a circular area, except that the moment of friction sought here involves the first power of the radii, and not their squares as in moment of inertia calculations. There will always be a value for $(D^3-d^3)/(D^2-d^2)$, affected little by the fact that $D-d$ may be very small. In other words, a friction moment of slightly reduced magnitude exists even when the contact area is a mere knife edge.

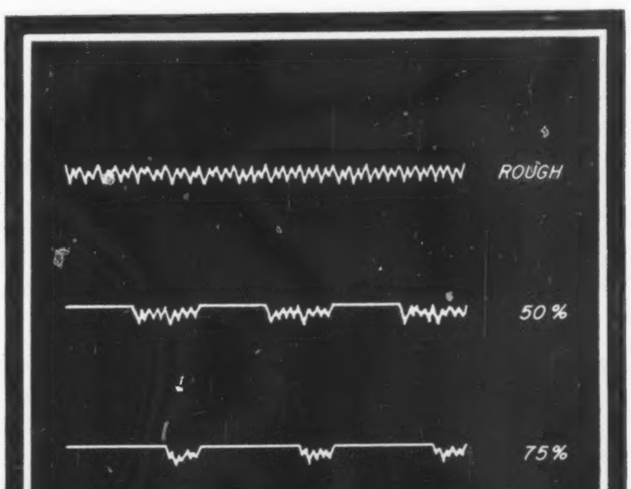
Coefficient of Friction

Friction coefficient can be kept low by good surface finish, lubrication, or selection of antifrictional materials. The designer does not always have a free hand in this respect. Lubricants generally find their way into the product being sealed, and if contamination is to be avoided their use may not be advisable. There are, also, some chemicals, such as nitric acid mixtures, which might cause nitration and explosion when ordinary petroleum lubricants are used with them, although safe lubricants for this purpose have been developed.

Sealing of oxygen should never be undertaken with ordinary oils or greases. Selection of materials is complicated by the fact that alloys developed in the past for general use in journals and sleeve bearings may become useless when exposed, as a seal must be, to corrosive vapors or fluids. Even the alloys developed for materials of construction in chemical work may be of little use as sealing faces if they depend for their corrosion resistance on the building up of a protective film or oxide during initial exposure. The faces must rotate against each other, and the usual film is either not formed at all or, if formed during idle periods, is soon rubbed off when motion begins.

Surface finish is a characteristic in which the seal designer is not usually limited, and it is therefore wise to specify the best surface obtainable whether the service is to be in viscous fluids such as oil or molasses or nonviscous ones such as ammonia or alcohol. As pointed out earlier, any reduction in absorbed power means increased seal life, and improved surface finish. Reducing the coefficient of friction, reduces power consumption regardless of the fluid being sealed. The sole exception to this is the case of full film separation of the faces which, as will be discussed later, practically never exists. Another reason why a good surface finishing process is desirable is that it can be designed to correct geometrical imperfections at the same time the surface itself is being finished.

Two sealing surfaces having equal scratch depths, usually expressed in microinches, may have very different coefficients of friction even though they are of the same material, run against the same mating surface, and seal the



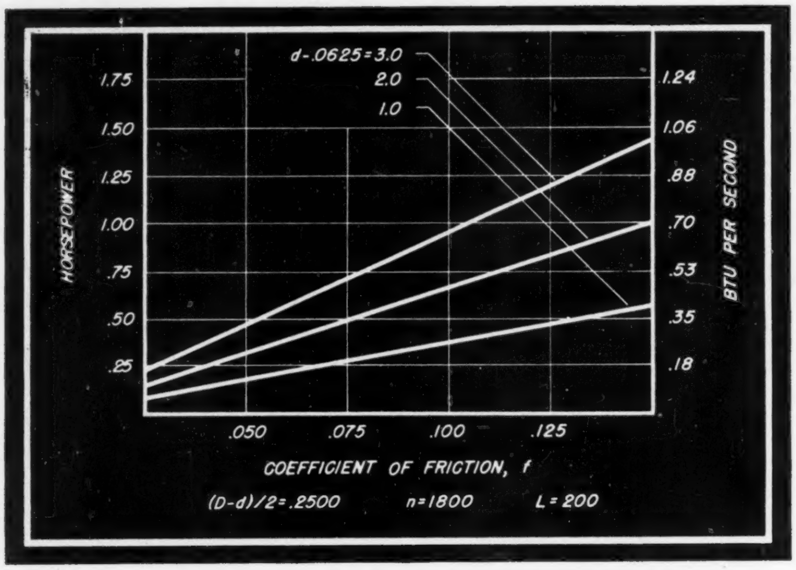
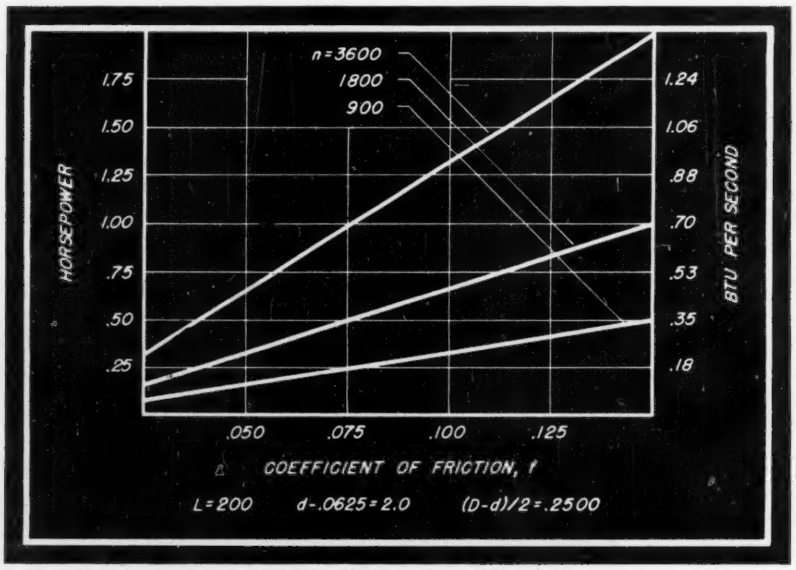
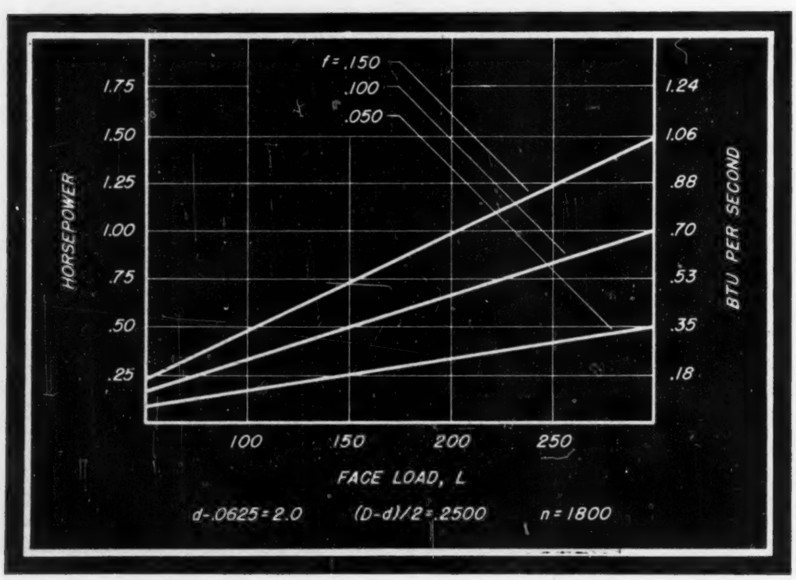


Fig. 33—Above—Coefficient of friction vs. horsepower for three different shaft diameters. Heat generation is also indicated

Fig. 34—Below—Coefficient of friction vs. horsepower for three different shaft speeds of 3600, 1800 and 900 revolutions per minute





same fluid. The reason is one may have a greater proportion of flat area than the other. If the grinding or turning operation which preceded the surface finishing operation on one, for example, produced more widely distributed peaks and valleys than on the other, when they are both finished to the same maximum scratch depth it will be found that the flat areas on one will constitute a greater percentage of the total area than is the case on the other. This is illustrated in *Fig.* 32, which shows four surfaces with the same scratch depth, but with different flat area percentages.

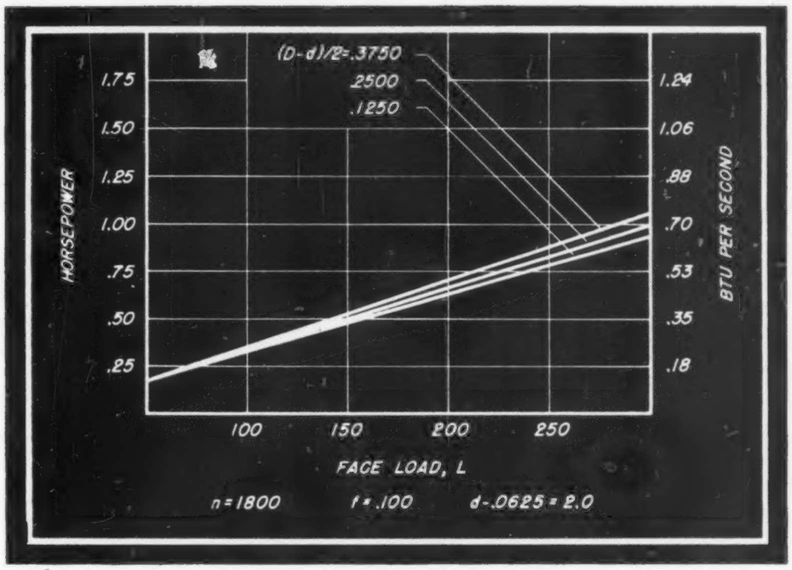
It is important, therefore, to specify the flat area percentage as well as the maximum scratch depth. For a given piece, of course, flat area percentage varies directly with scratch depth, but profile patterns after rough semifinishing operations are not expected to be uniform on all pieces. Indeed, it would be difficult to produce such uniformity. Generally, it is simpler to specify the flat area percentage and scratch depth. The most desirable surface for mechanical sealing is one of maximum flat area percentage and minimum scratch depth.

If alignment between the axis of rotation and the machine surface which determines the position of the stationary face cannot be controlled closely, and if the stationary member is not self-aligning, it is likely that the care taken to produce a good surface finish will be wasted because there usually will have to be some wearing in. This process, by its very nature, changes the stationary surface, and along with it usually goes a change in the rotating surface, too. When the faces are finally worn in they may have many annular corrugations. Since these corrugations mesh perfectly, good sealing is not precluded, but the original surface might just as well have been rough ground or turned. An interesting example of this is shown in *Fig.* 30, a rotating surface, and *Fig.* 31, a stationary one, which wore in together, and which sealed satisfactorily in spite of the fact that the corrugations were as much as 0.018-inch deep. Failure took place in the stationary face due to the fact that lubrication was unintentionally cut off, with consequent galling.

Lubrication, where it can be used, not only reduces the friction coefficient, but it also provides a sort of cork which is helpful to good sealing. If two flat surfaces are brought together to a position in which there is no relative motion it will be found that the presence of a fluid between them

Fig. 35—Left—Face load vs. horsepower for three different coefficients of friction

Fig. 36—Right—Face load vs. horsepower for three different seal face widths



will permit the sealing of much higher pressures than if they were dry. This is probably due to the forces of adhesion and cohesion in the fluid and, if it can be maintained between the faces, remarkably high pressures are sealable. With the best oils obtainable for the purpose, however, a full fluid film ceases to exist when the face load exceeds about 5 psi. When there is relative motion between the faces other forces are introduced which tend to rupture the film at even lower loads.

Seal designers, consequently, should not expect full fluid lubrication between the faces. Metallic contact is virtually inevitable, there being no hydrodynamic forces to form a lubricant wedge such as in a sleeve bearing, and for this reason it is wise to select bearing materials of good antifrictional qualities. Carbon or graphite is excellent for general use, and it has the additional advantages of being nongalling and resistant to a wide range of chemicals. Bronzes, especially the high-lead alloys, are used extensively and, although they are not as antifrictional as carbon or graphite nor as widely resistant to corrosion, they are not as brittle and therefore not subject to breakage from shock or vibration.

The rotating surface is generally the harder one, especially on seals whose stationary members are not self-aligning. The reason for this is that if any wearing in is necessary due to lack of normality between the stationary surface and the axis of rotation the correction takes place in the stationary face, not the rotating one. The rotating face is therefore either hardened, nitrided, or hard faced with some material such as Stellite. Here, again, it must be kept in mind that the surface often is subject to corrosion and also that the fluid between the faces may be at a high temperature. An alloy in the seat of a valve connected to a pump, for example, may be suitable at the given pumping temperature, but it may be useless in a mechanical seal in the same pump where a temperature rise of 200 F at the sealing faces would not be at all unusual.

Shown in *Fig.* 33 are curves for absorbed power and heat generation for shaft diameters of 1, 2 and 3 inches with friction coefficients from 0.025 to 0.150, face width being ¼-inch, speed 1800 rpm, and total face load 200 pounds. *Fig.* 34 shows the same relations, excepting the shaft diameter is assumed to be 2 inches and the curves

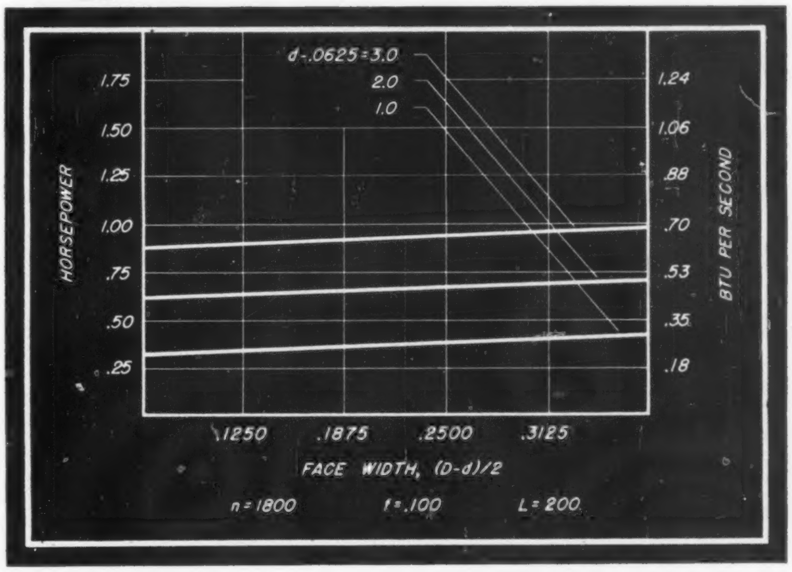
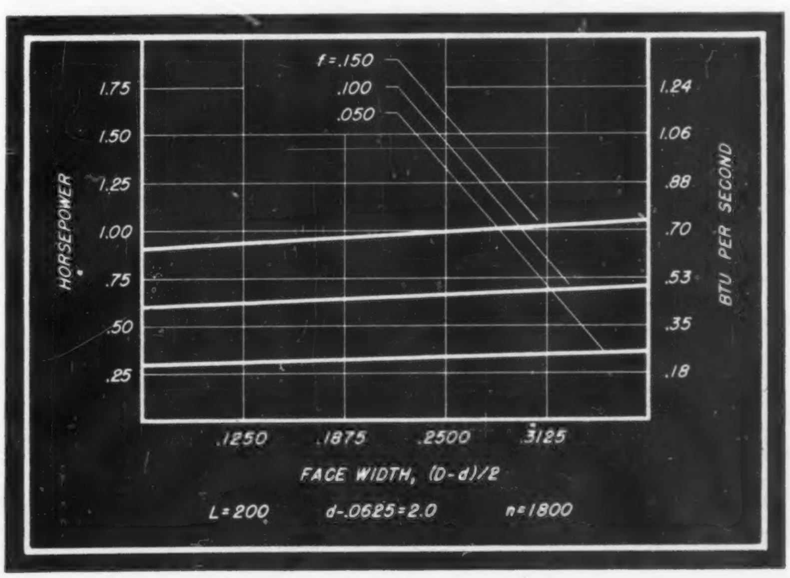


Fig. 37—Above—Face width vs. horsepower for three different diameters of shafts, 1, 2 and 3 inches

Fig. 38—Below—Face width vs. horsepower for three different coefficients of friction, indicating heat generated



are for speeds of 3600, 1800, and 900 rpm. In both illustrations it can be seen that the ratio of friction coefficient to power consumption is constant. In *Fig.* 34, for example, the consumption for a coefficient of 0.075 on the curve $n = 3600$ is about one horsepower. If the coefficient is doubled to 0.150, the consumption is doubled to about two horsepower.

Face Load

What mathematical relationship should exist between the quantity L and the pressure to be sealed, or whether there is any relationship, has been the source of much discussion among seal designers. It is still a controversial point, and understandably so, since it lies at the root of the whole sealing problem. The total face load L may have one of five different values, depending on the design of the seal. The first is the case where the contact area is equal to the effective area against which the fluid pressure works to force the faces together, so that

$$L = P\frac{\pi}{4}(D^2 - d^2) + k$$

where P = fluid pressure in pounds per square inch and k = load in pounds due to springs or strained member.

Second is the case where the contact area does not have the same value as the effective area against which the fluid pressure works, the resultant force still being in a direction to force the faces together. L becomes the spring or strained member load plus the product of the fluid pressure and the effective area. Where bellows are used the effective area usually can be obtained from the bellows manufacturer. It should be noted, however, that when speaking of a bellows effective area the manufacturer is thinking of a bellows with a closed end. When the bellows is applied to a mechanical seal the area of the shaft must be taken into consideration.

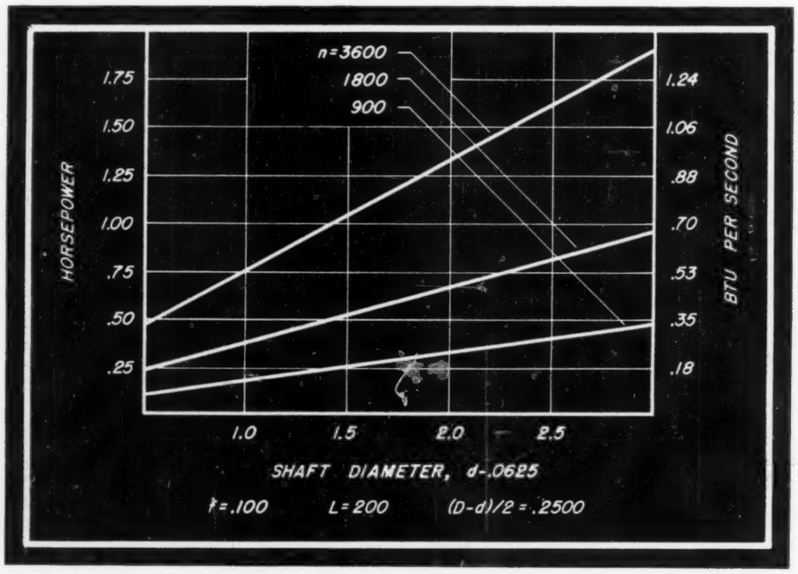
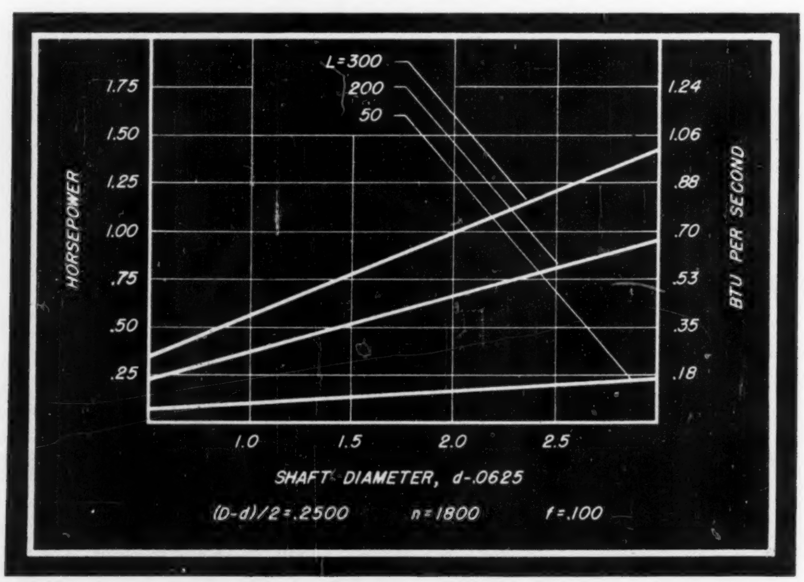


Fig. 39—Above—Shaft diameter vs. horsepower for three different shaft speeds of 3600, 1800 and 900 revolutions per minute

Fig. 40—Below—Shaft diameter vs. horsepower for three different seal face loads of 300, 200 and 50 pounds



In the third case the contact area is equal to the effective area, but the force is in a direction which tends to separate the faces, so that $L = k - (P\pi/4)(D^2 - d^2)$. The fourth case is similar, except that the contact and effective areas are not equal, making the face load the difference between the spring or strained-member load and the product of the fluid pressure and effective area. In the fifth case the face load is unaffected by the fluid pressure, resulting in a "completely balanced" seal. So far as the writer is able to determine no such seal is available at present, and none is in use. Whether such a seal would have any advantages over an unbalanced one is open to debate. The question involves fundamentals which are not fully understood.

If one reflects on the first four cases outlined, an interesting and closely related problem comes to mind. It is plain that L may become so great that galling, seizure, or even fracture takes place. In the third and fourth cases, however, L may become zero or negative. If it is less than zero the faces tend to separate. What would happen if this tendency were interrupted at precisely the point where a cohesive and adhesive film of minimum thickness would be permitted to form between the faces? Would the seal leak? Upon what characteristics of the fluid would leakage, if any, depend? In other words, when L is zero but the faces are each in contact with a very thin fluid film, what factors are involved, and to what extent, in determining rate of leakage? It is assumed, of course, that the faces cannot be separated by more than a predetermined amount.

Plot of power absorbed and heat generated is shown in *Fig.* 35 for face loads from 50 to 300 pounds, with friction coefficients of 0.050, 0.100, and 0.150. A shaft diameter of 2 inches, a face width of ¼-inch, and a speed 1800 rpm are assumed.

(*Concluded on Page* 184)

MACHINE *Editorial* DESIGN

Design for Sales Appeal

It is common observation that today's overwhelming demand will absorb goods of almost any kind, too many of us having at one time or another been obliged through necessity to purchase articles which we would never have considered had there been others from which to choose. However, all indications point to the current pent-up demand soon becoming more nearly satisfied through the easing of materials and labor shortages and a return to natural laws governing price structure. When that time comes, unenviable will be the position of the manufacturer who has failed to pay the strictest attention to designing for salability.

Contrary to popular impression the art of designing for salability, or industrial design, is concerned with a great deal more than mere styling. The idea seems to persist that it is sound practice to design a machine solely from mechanical considerations, then, by means of a few sheet-metal or plastic housings, superficially "streamline" it to catch the buyer's eye. Like every other phase of design, industrial design involves a fine balance between the requirements of appearance, convenience in use, accessibility for maintenance and repair, adaptability to mass production, and marketability. Unless all these factors are taken into careful consideration at the outset, and proper relative values assigned to each, there can be no guarantee of ultimate success. For example, although it would be foolish to sacrifice accessibility for appearance in a production machine, this appears to be an accepted principle in passenger automobile design.

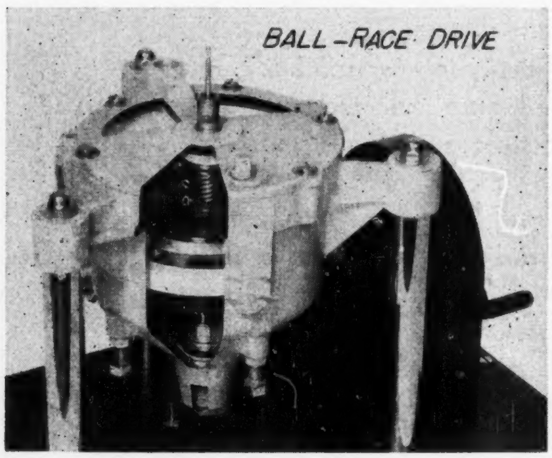
Belated recognition of the importance of designing for salability has prompted the formation in Britain of a government-sponsored Council of Industrial Design, a report on which appears elsewhere in this issue. While it is not suggested that government assistance is either necessary or desirable in matters affecting design in this country, American designers cannot afford to overlook the effects of such subsidized efforts, leading to stiffer competition in world markets.

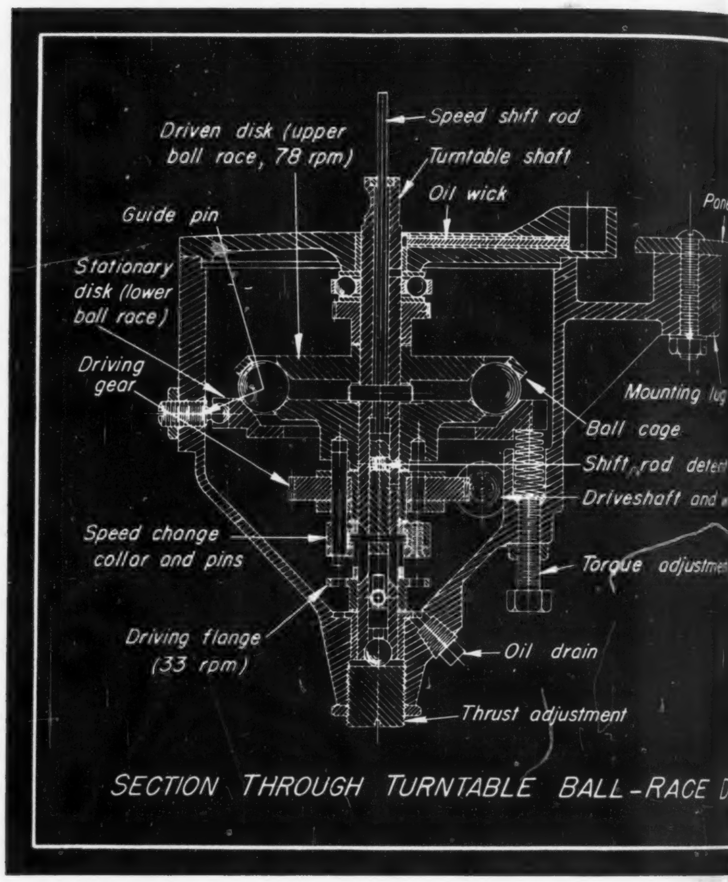
It cannot be too strongly urged that engineers redouble their efforts to create designs that will be irresistible to the prospective buyer, particularly in view of the threatened reduction in demand in the relatively near future. While this may include some judicious application of enclosures in certain instances, in the majority of machines it does not mean the hiding of working parts and provision of decorative trim as much as it means imparting to the complete unit an appearance that suggests thoroughly competent design.

DESIGNS OF THE

Transcription Turntable Employs Ball-Race Mechanism in Drive

Designed for professional use to meet laboratory, broadcast (AM and FM), moving picture, facsimile, and wire photo requirements, this turntable employs an 1800-rpm synchronous motor geared at a 24 to 1 ratio to the turntable shaft. Instantaneous variations in turntable speed within a single revolution have been reduced to less





than 0.15 per cent at 33 1/3 rpm and to less than 0.20 per cent at 78 rpm. These tolerances are possible because of precision alignment and accurate fitting of parts in the two-speed drive. The 33 1/3-rpm speed is obtained through a double-thread worm and gear, the worm and motor shafts being connected with a special rubber coupling in which no metal parts of motor and drive come into direct contact. Power is applied to drive the table at 78 rpm through the ball race mechanism shown in the cross section drawing. Minute tolerances must be maintained in the diameter of the six steel balls; in the machined, polished, hardened-steel race in which the balls operate; and in all alignments involved.

The motor, of 1/25 rated horsepower, is of the condenser-start, condenser-run type with excellent starting and running characteristics. The starting curve is not too steep, avoiding the danger of shock which might jar the pickup from the groove, and there is plenty of reserve power to maintain constant speed. A certain desirable amount of positive "loading" in the drive mechanism keeps the motor pulling constantly, thus avoiding undesirable "hunting" and consequent unstable speed conditions.

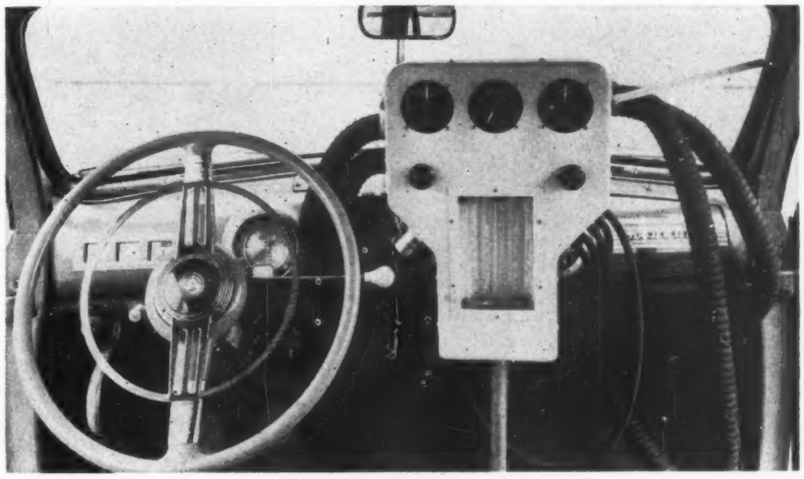
Drive is in an aluminum "pot" with dustproof cover,

and all working parts are immersed in a light oil of about SAE 10 viscosity. This acts as a filter to obviate vibration and noise transference to the turntable.

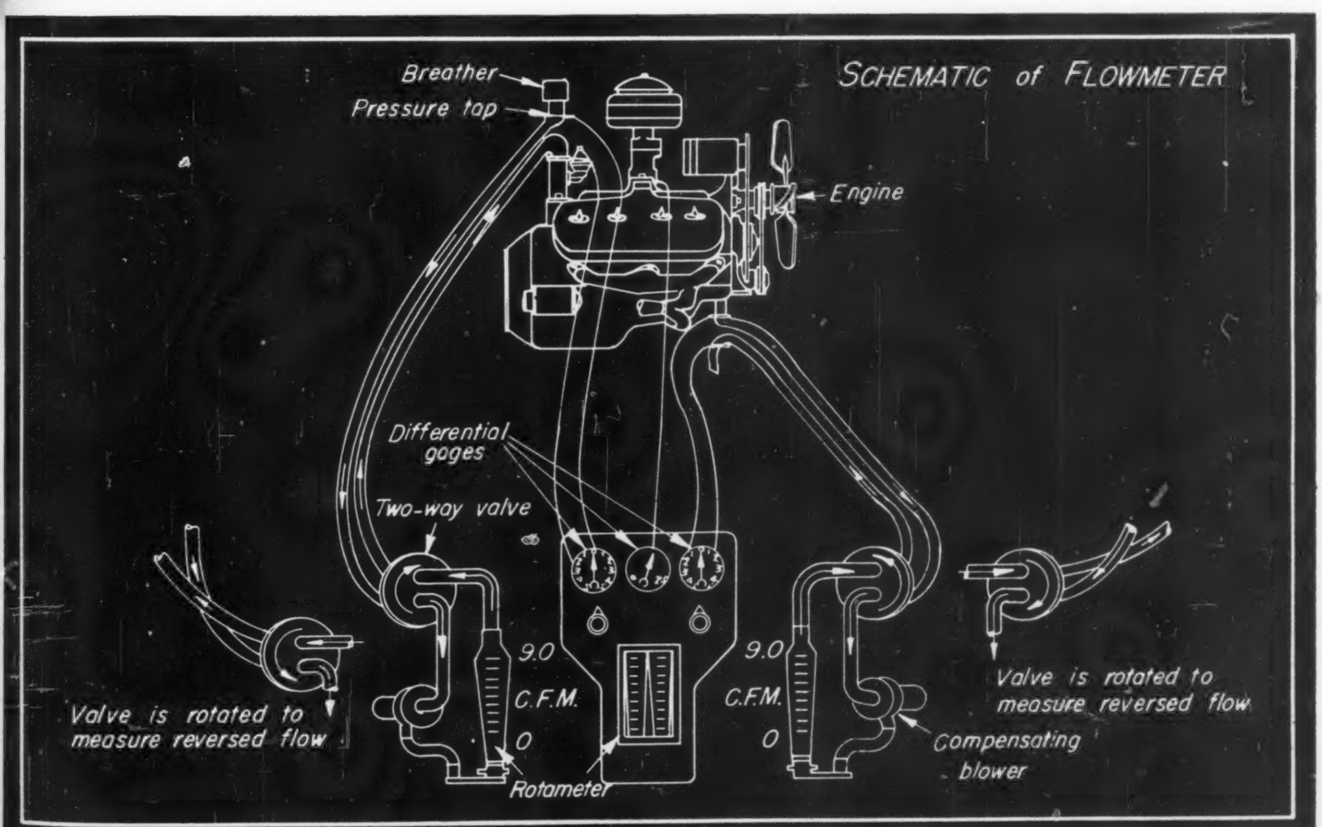
Extremely low noise level is obtained in this turntable because of the characteristics of the motor and drive already described and also because there are two vibration dampers in the linkage between the drive and table. The second of these dampers is in the form of a clutch which makes for smoother starting and stopping of the table. Table reaches stable speed in less than ½ revolution at 33 1/3 rpm and in less than 1½ revolutions at 78 rpm from motor switch operation. Cabinet is provided with adjustable feet for leveling, and a door at the front of the cabinet facilitates servicing of the drive, motor and other mechanisms. Machine is finished in satin black lacquer. Manufacturer: Fairchild Camera and Instrument Corp., Jamaica 1, N. Y.

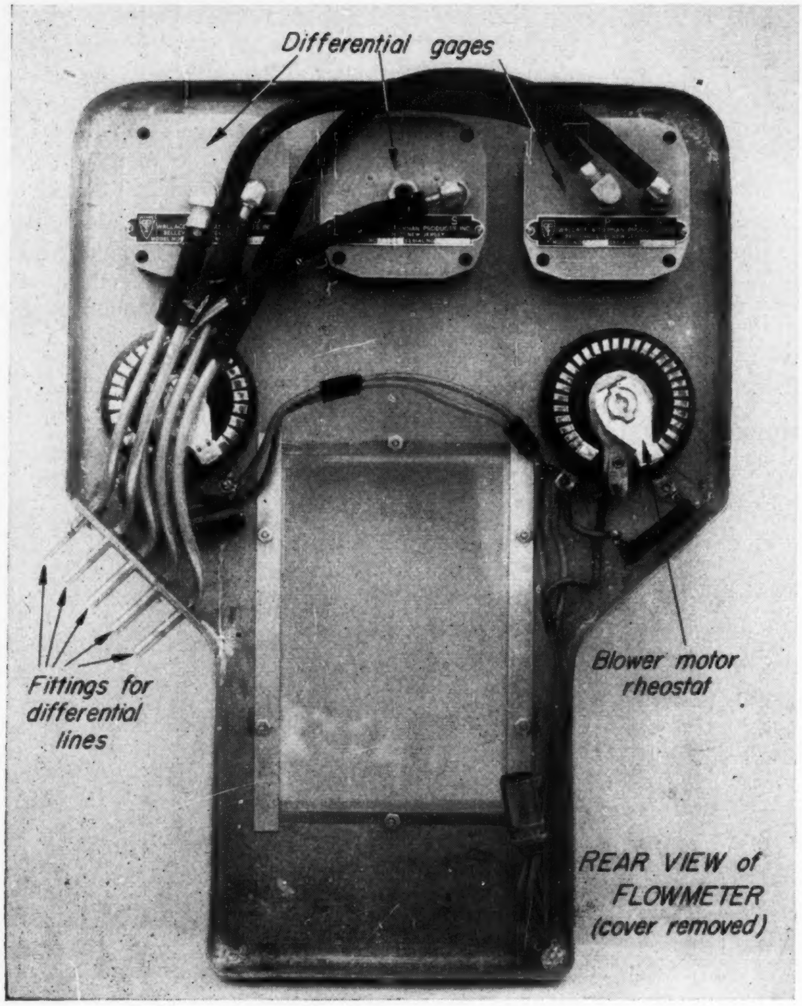
Flowmeter Measures Crankcase Ventilation

This instrument, used to measure air flow through an engine, is designed to be installed and used in an automobile under actual operating conditions. Instantaneous readings are taken and have far greater value than average readings taken over a period of time or distance.



As the schematic diagram below shows, the flowmeter is actually two duplicate instruments built as one. For convenience, they will be referred to as "left" and "right". The left instrument measures the flow of fresh air entering the engine, while the right instrument measures the total outlet flow. To permit such measurement it is necessary to introduce the flowmeter into the normal





REAR VIEW of FLOWMETER (cover removed)

tilation, the inlet breather of the engine is maintained in its normal position but disconnected from the engine and connected by flexible hose to the "in" connection of the left flowmeter. A second tube is then used to connect the meter "out" connection to the engine at the point where the breather formerly was connected. Thus air flowing into the engine enters at the breather, passes through the connecting tube into one side of the two-way valve, through the blower unit where compensating pressure for any line drop is built up. through the rotameter where the flow is indicated, and then returns to the engine through the other side of the two-way valve.

Pressure taps are located at each of the connecting points in the engine and are connected by tubing to the left differential gage. Thus when the blower maintains a differential pressure of zero between these two points, there is no restriction added to the normal setup and the ventilation system will function in its normal manner. In the same way the engine outlet is interrupted and connected to the right side of the instrument with pressure taps at the break connected to the right differential gage. All other openings in the crankcase or engine must be plugged to permit all air entering and leaving the engine to pass through the flowmeter. Manufacturer: Ford Motor Co., Dearborn, Mich.

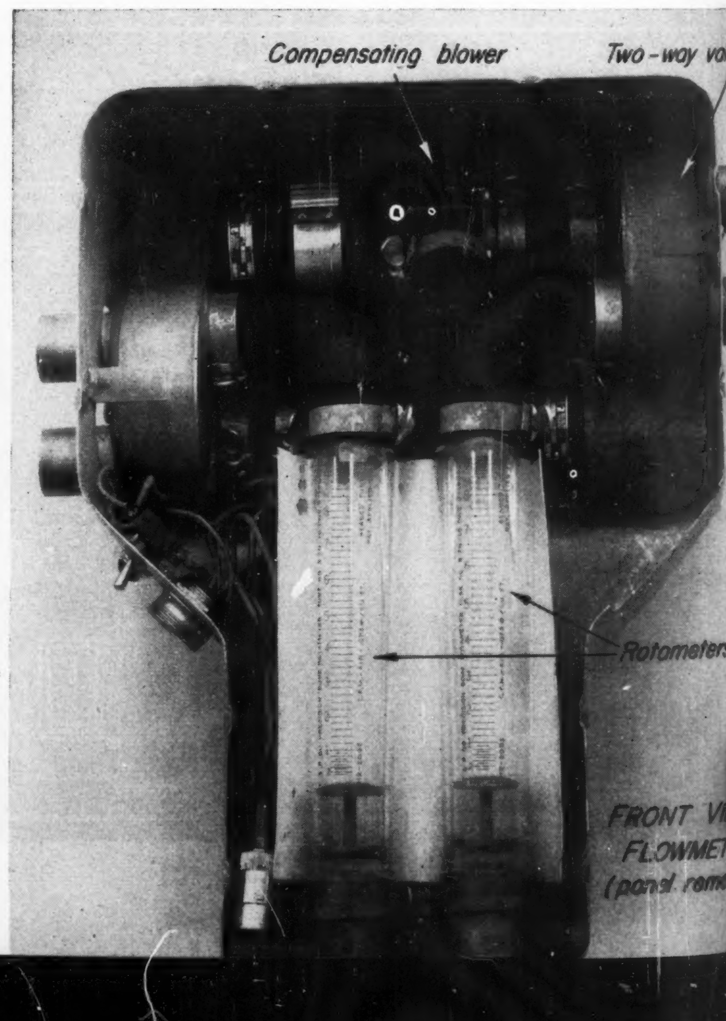
ventilating system of the engine. This is accomplished by interrupting the system at the inlet and outlet openings and inserting the appropriate side of the instrument by means of flexible hose.

The added restriction imposed by the hoses and meter is compensated for by means of built-in variable-speed blowers which are driven by electric motors controlled by rheostats. Each side of the flowmeter comprises a rotameter and an attached compensating blower. The rotameter permits direct reading of air flow in cubic feet per minute and is graduated to enable reading from one-tenth to nine cubic feet per minute. Resistance of the meter and lines is indicated by a differential gage which has a range of -5 to 0 to $+5$ inches of water.

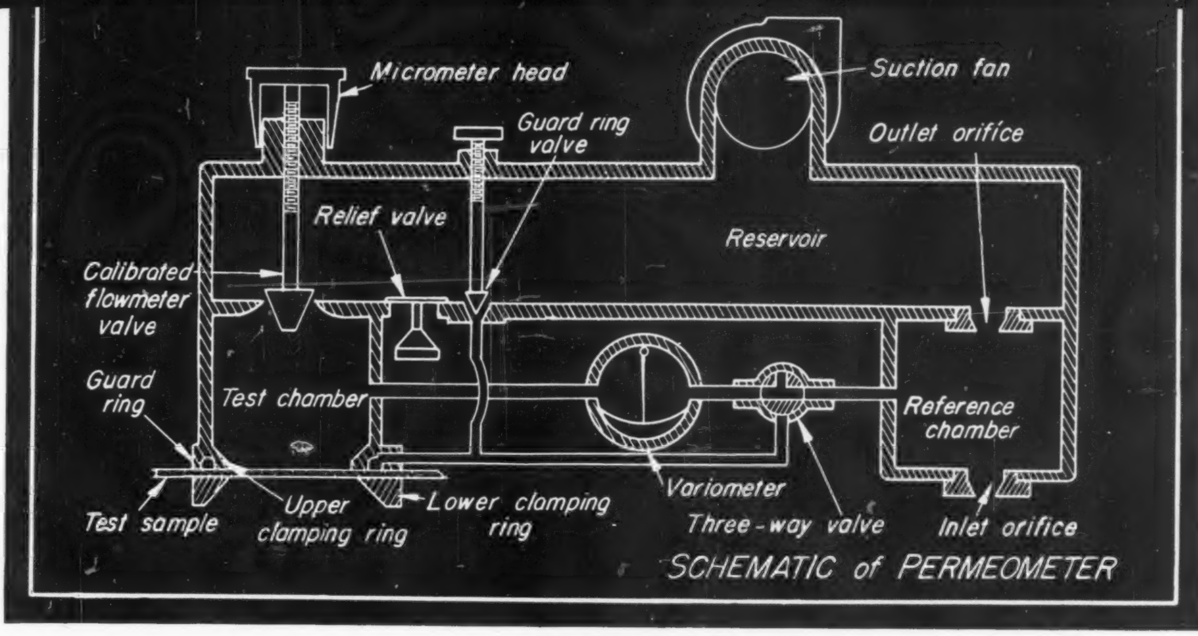
Valve Permits Measuring Reverse Flow

Each side of the instrument includes a two-way valve which permits flow measurement under conditions of reverse flow. This is needed in order to maintain the same direction of flow through the blower and rotameter. In addition to the differential water gages, a gage which indicates manifold vacuum in inches of mercury is included for use under various test conditions.

When the instrument is used to measure ven-



FRONT VI FLOWMET (panel remo

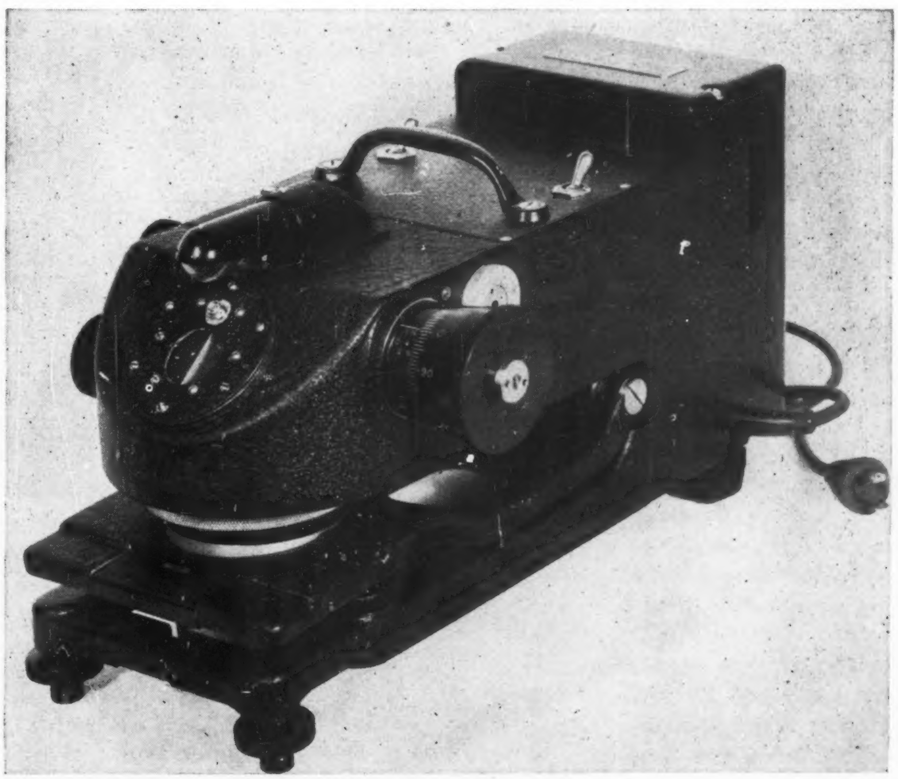


Air-Permeability Tester for Porous Sheet Materials

Used for testing the air permeability of textile fabrics, porous paper and other porous sheet materials, this "permeometer" is in principle a pneumatic bridge, its use being analogous to that of the Wheatstone bridge in the measurement of electrical resistance. Arrangement of components and functioning are shown in the schematic drawing above.

A suction fan exhausts air from a reservoir, suction in which is maintained at 10 inches of water by a gravity-actuated relief valve. Air is drawn from the atmosphere through two parallel chambers into the reservoir. In one of these, the reference chamber, a suction of 0.5 inches of water is maintained by stainless steel inlet and outlet orifices. In the other, the test chamber, the suction is determined by the permeability of the sample under test and by a calibrated flowmeter valve. This valve, operated by turning a micrometer head, is adjusted until the suction in the test chamber balances the suction in the reference chamber, as indicated by zero reading of the vane in a variometer connecting the two chambers. The valve reading is then the measure of the air permeability of the sample. Any remaining slight variations of the low pressure source are reflected equally and simultaneously in the two chambers. Thus, nc valve adjustment need be made to maintain a null reading on the variometer.

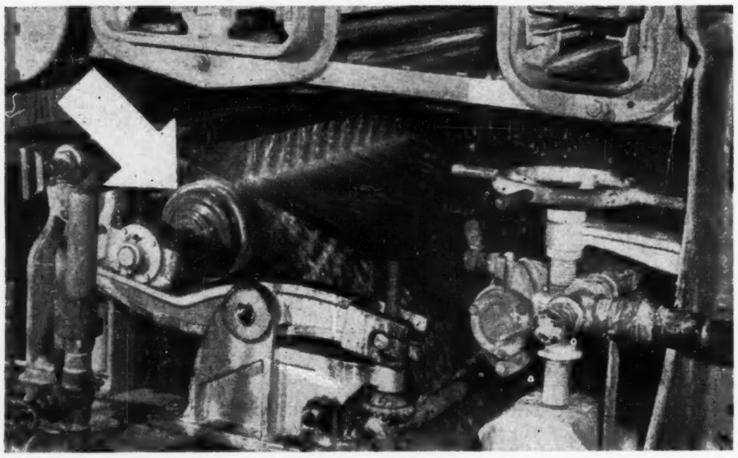
A guard ring (groove in the upper clamping ring) is connected through a needle valve to the reservoir, and through a 3-way valve to the variometer and reference chamber. Adjustment of the needle valve balances the suction in the guard ring. This eliminates from the measurement any air that is drawn across the clamped surface of a rough sample, and makes unnecessary excessive clamping pressure. Micrometer valve reading can be converted into air permeability by reference to a calibration curve or table. Manufacturer: W. & L. E. Gurley, Troy, N. Y.



DESIGNS OF THE MONTH

Applications

of engineering parts, materials and processes

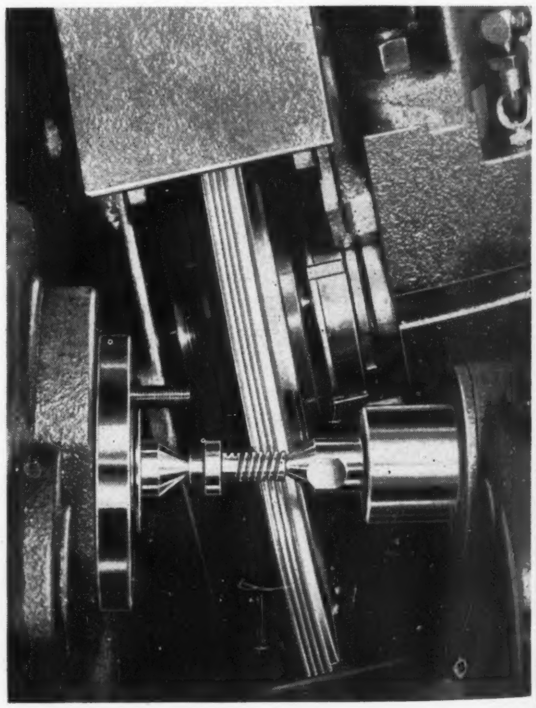


Solves Cleaning Problem

INTERESTING solution to the problem of cleaning Fourdrinier screens, used in the manufacture of paper, may be seen in the illustration, above. Pulp is floated upon this extremely fine wire screen and in order that drainage may proceed at a high rate, it is essential that the mesh be kept open. In the past, shut downs for cleaning have resulted in inordinate time losses. To solve this problem, spiral-wound stainless-steel wire brushes manufactured by the Pittsburgh Plate Glass Co. have been installed at the point where the screen leaves the paper. Driven by meshing with the Fourdrinier screen, the brush wires enter the openings of the screen to remove the pulp fibers which are then washed away by water.

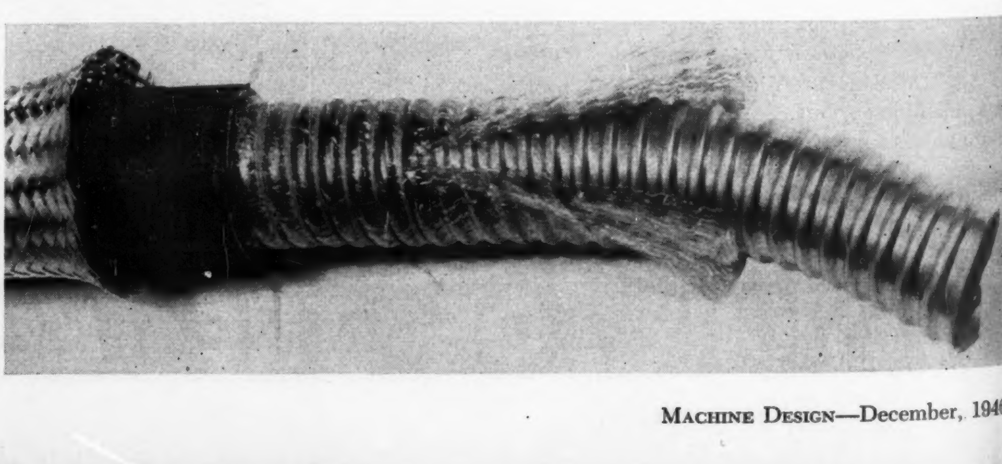
Speeds Precision Manufacture

BRONZE double-lead worm, below, was manufactured to a pitch-diameter tolerance of 0.003-inch in 35 seconds on a Sheffield crush grinder. A multi-ribbed, crush-formed grinding wheel, set at the proper helix angle, is plunged to depth near the outer end of the part and retracted near the shoulder. So produced, the worm is free from burrs and has a finish superior to that obtained when common machining methods are employed. Time saved is up to 94 per cent.



Cellulose Provides Sealing Medium

USE OF a common material to solve an unusual problem is evidenced in the Avioflex hose, below. Designed to transmit hydrocarbons, the hose is also required to withstand severe flexing and rough treatment. Use of laminated cellulose sheet, wrapped and sealed around a spiral metal tubing, maintains flexibility over a wide temperature range and keeps the hydrocarbons from contacting the synthetic rubber cover.



Nomograph Aids Determination of Torsional Stresses in Shafts

By Carl P. Nachod
Vice President
Nachod & U. S. Signal Co. Inc.
Louisville, Ky.

HORSEPOWER H transmitted by a shaft D inches in diameter, turning at N rpm, will cause a torsional fiber stress of S psi. Equating the expressions for torque,

$$\frac{\pi S D^3}{16} = \frac{63100H}{N}$$

or

$$0.196SD^3 = \frac{63100H}{N} \qquad (1)$$

Solving for H

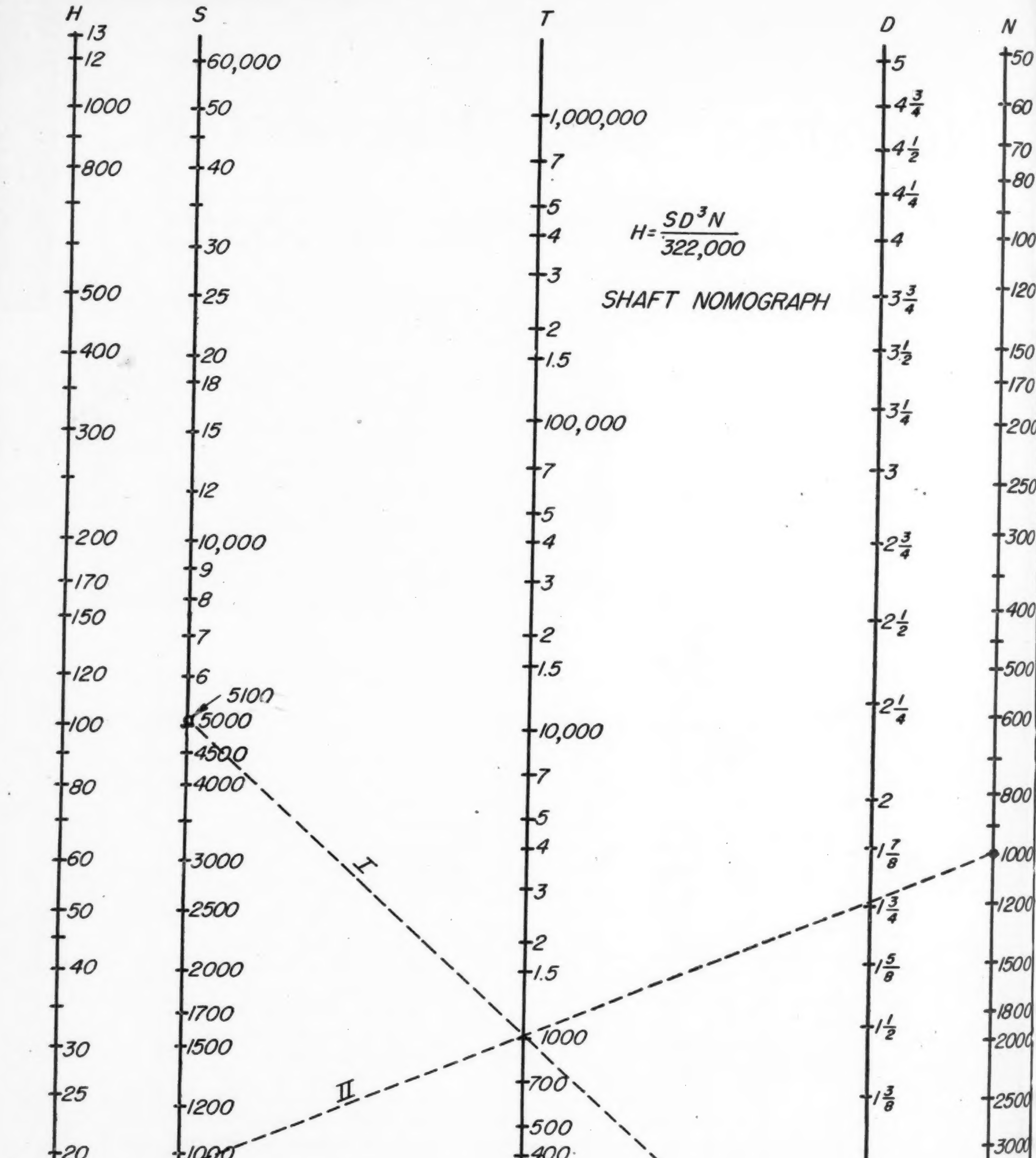
$$H = \frac{SD^3N}{322000} \qquad (2)$$

From Equation 2 the horsepower varies directly as the stress, directly as the speed and directly as the cube of the shaft diameter. Thus comparing 1-inch and 2-inch diameter shafts at the same speed and stress conditions, the 2-inch shaft will deliver 8 times the horsepower. The permissible stress S varies with the uniformity of the load, being lowest for sudden reversals of load and long shafting, higher for fluctuating loads, and highest for ordinary uniform loading service.

Equation 1 has been made into a nomograph of 5 scales, vis: H, S, T, D, and N, which is shown on the following page. The two dashed computing secants indicate, for example, that a shaft delivering 15.85 hp at 1000 rpm (secant I) will be stressed to 5100 psi if it is 1-inch diameter (secant II). One secant must connect the two inner scales, and the other, the outer scales. Both secants must intersect on the middle scale which is the turning scale and ordinarily is not graduated; however, inasmuch as each side of Equation 1 represents torque, the middle scale is useful for calculating torque T. In this case it is seen to be 1000 lb-in.

To construct this nomograph, locate the scales conveniently on the paper, making them exactly symmetrical with the middle scale. From the left the graduations start from the base line at 10, 500, 100, 1, taken arbitrarily, and 6440 respectively, the latter being figured from Equation 2 with the foregoing values substituted.

For the H and S scales the modulus—length of the log scale from 1 to 10, 10 to 100, etc.—may conveniently be made 12.5 cm, which is the length of one cycle on the A or B scale of a 10-inch slide rule. (Due to reduction in size, the modulus for the chart on the following page is somewhat less than 12.5 cm). Inasmuch as D is cubed, its modulus is $3M$; since N is in the denominator of Equation 1 its modulus is $-M$, that is, it increases downward; and since the T-scale is midway between the outer scales its modulus is $M/2$. The graduations for $M/2$ and $3M$ may be drawn by simple proportion. Other means of graduation are from ruled log paper or by calculation.


H
S
T
D
N
H=SD^3N/322,000
SHAFT NOMOGRAPH
5100
15.85
I
II
Horsepower H
Fiber Stress S (psi)
Torque T (lb-in.)
Shaft Diameter D (inches)
rpm N

ASSETS to a BOOKCASE

Mechanics for Engineers

By E. R. Maurer, R. J. Roark, and G. W. Washa, professors of mechanics at the University of Wisconsin; published by John Wiley and Sons, Inc. New York; 425 pages, 5⅝ by 8⅝-inches, clothbound; available through MACHINE DESIGN, *$4.00 postpaid.*

A good reference text on the rudiments of mechanics, this book is based on the well known volume, *Technical Mechanics,* by Maurer and Roark, and covers in a concise manner statics and dynamics as applied to engineering problems. Rewritten and amplified, it endeavors to present basic principles with clarity, and to this end carefully illustrates its theoretical discussion with problems graded in order of difficulty.

The book incorporates a number of new approaches. In statics considerable attention is given to problems involving non-coplaner forces. In dynamics, kinematics and kinetics are considered concurrently rather than separately. The methods of vector analysis have been used more generally in discussion of motion, and d'Alembert's principle has been given greater emphasis as an aid to such work as dynamic stress studies.

The text is well illustrated with examples and sketches, and evidences no attempt to use mathematics of a higher order than is necessary for basic applications. Discussed in addition to subjects already mentioned are: Impulse and momentum, work and energy, three-dimensional motion, vibration, and dimensional analysis.

□ □ □

Lincoln's Incentive System

By James F. Lincoln, President, the Lincoln Electric Co., published by McGraw-Hill Book Co., New York; 192 pages, 6 by 9 inches, clothbound; available through MACHINE DESIGN, *$2.00 postpaid.*

By using the methods described in this book economic strides that are unprecedented have been made. From the year 1932 the Lincoln Electric Co. has reduced labor costs as much as 90 per cent, thereby increasing payments to stockholders and cutting consumer prices 40 to 60 per cent. At the same time, wage rates have averaged higher than those of any other manufacturing activity in the world.

It is Mr. Lincoln's belief that the price of a commodity should be in proportion to the manufacturing cost. Further, that cost may be reduced by increased manufacturing efficiency (largely produced by piece-work incentive), and a not inordinate dividend to stockholders. He points out that it is to the interest of worker and management to work together to increase profits (if they are divided proportionately) rather than to be at each others throats in collective bargaining. The crux of the plan seems to be in the philosophy of working to produce a better product at a lower price, rather than purely to make a profit for absentee stockholders. The book is provocative, thoughtful, and tends to wag an accusing finger at union, capital and government.

□ □ □

An Introduction to Electronics

By Ralph G. Hudson, professor of electrical engineering, Massachusetts Institute of Technology; published by The Macmillan Co., New York; 93 pages, 5¾ by 8⅝ inches, clothbound; available through MACHINE DESIGN, *$3.00 postpaid.*

Were this book but another in the plethora of volumes concerning the elements of electronics, it would not be reviewed here. Professor Hudson has, however, contrived to bring to his reader a viewpoint that is at once refreshing and basic. To the engineer in fields other than electronics, yet occupied in work that concedes the usefulness of the new tool, this book is suggested reading. In no other source known to this publication is the physical background of electronics, coupled with the principles of application, discussed more nearly at the mechanical engineer's level.

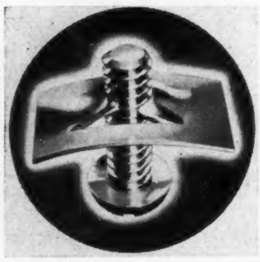
Covered first are: The principles of matter, the electron, positron, the cyclotron, and electric current. Thence to thermionic emission and the vacuum tube, radiant energy, oscillation and modulation. From basic concepts the author turns to applications, discussing light, television, power control and the more complicated electronic devices such as the electron microscope.

While short, the book covers its subject well, is amply illustrated and factual in its information. Mathematics is avoided in discussions although elementary writing and "talking down" are nowhere in evidence.

Intended to simplify engineering calculations related to the design and manufacture of products based on involute curves and surfaces—such as gears, gear tool supplies, etc., is the book "Involutometry and Trigonometry" by Dr. Werner F. Vogel and published by the Michigan Tool Co. The remarkable tables give seven-place natural functions for every hundredth of a degree, and in addition provide numerous mathematical tables and charts to simplify gear design. An unusual table in the appendix of the book provides a means for a large-scale layout of gears by polar coordinates alone. Numerous new gear layout formulas, and dimension tables serve to expedite design. The book contains 321 pages, measures 8 by 11 inches, and is available at $20.00 from the Michigan Tool Co., 7171 E. McNichols Rd., Detroit.

new parts and materials

Locking Fasteners

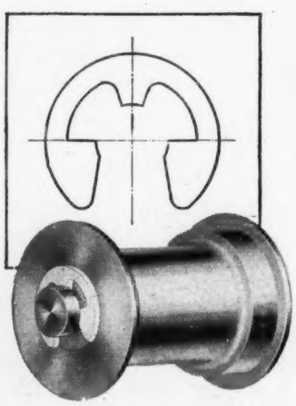


NEW LINE of heat-treated spring-steel locking fasteners known as the C7000 Speed Nut series is now available from Tinnerman Products, Inc., 2085 Fulton Rd., Cleveland 13. The new Speed Nut line has been engineered to a precision formula based on the diameter and strength of the screw with which it is used. The nuts, as a result, are more compact, withstand higher tightening torque and provide greater tensile strength than any of the flat-type Speed Nuts announced previously.

Welding Electrode

WELDING ELECTRODE with new type extrusion coating having numerous valuable properties has been announced by the Air Reduction Sales Co., 60 East 42nd St., New York 17. The new electrode works equally well with either alternating or direct current, and has little tendency to pick up moisture. Other advantages claimed for the rod are: No slag interference, all-position welding, easy slag removal, and solid, dense deposits with an absolute minimum of porosity.

Retaining Ring



TYPE E retaining rings are the latest addition to the line of rings manufactured by the Truarc Sales Division, Waldes Kohinor, Inc., 47-10 Austel Place, Long Island City 1, N. Y. The new E-shaped ring is designed for small shafts, and provides an unusually large and uniformly protruding shoulder on shafts 3/32 inch diameter and over. The new ring is sprung into a comparatively deep groove and is designed to withstand considerable thrust loads. Three protrusions, equally spaced, form the abutments in the groove of the shaft. Recesses between the protrusions make the ring sufficiently resilient to permit spread for easy, quick assembly and disassembly without permanent set. The ring has wide possibilities for application in all types of business machines, radios, instruments, etc., and is said to be ideally suited for applications where a shaft is inaccessible in the longitudinal direction.

Pushbutton Units

LINE OF OIL-TIGHT pushbutton units, selector switches, and indicating lights designed especially for the machine tool and automotive industries has been announced by the Control Division of the General Electric Co., Schenectady. The momentary-contact pushbutton units are available in several forms: Single-pole unit provides normally-open and normally-closed circuit; three-point unit provides two normally-open circuits with common connection; double-pole units are available with either normally-open or normally-closed circuits. All contacts are the double-break type and made

of silver. Selector-switch unit is available in single-pole double-throw, or double-pole single-throw forms. Indicating light units have same single-pole mounting arrangement as the pushbutton units and selector switches. They are available for use on 110-125 or 250 volts, ac or dc circuits.

Solenoid Valve

AUTOMATIC solenoid valve useful for a wide range of applications is announced by the Johnson Corp., Three Rivers, Mich. New valve combines immediate full flow with the ability to operate under differential pressures as high as 150 pounds. It can be used for all types of liquid-level control, with hot and cold water, steam, oil and other processing liquids. The valve is direct-acting, not pilot operated. The solenoid is conservatively rated and a lever arrangement provides ample power to insure positive opening of the valve. The single-seat construction eliminates the trouble sometimes encountered with pilot-operated valves when silt or other foreign matter freezes the piston, and also increases the temperature range and enables the valve to handle hot liquids or steam up to

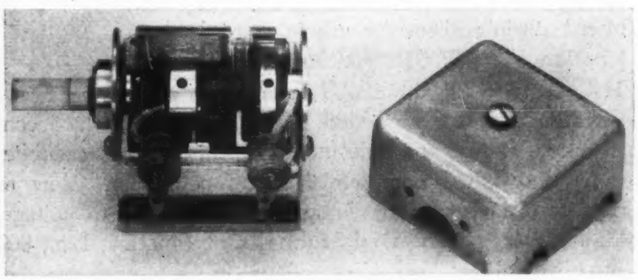
365 F. The valve is designated as a globe screwed type and is built for heavy duty service, with body of cast iron or bronze tested to 150 psi. Valve, seat and valve stem are stainless steel. The unit is available in two types: HH in sizes from ½ to 1½ inches, and HL in sizes from 1 to 3 inches. Standard models are furnished for operation on 110, 220, or 440-volt 60-cycle current.

New Electric Wire

AIRCRAFT wire said to reduce fire hazard and lighten weight of equipment has recently been announced by the United States Rubber Co., Rockefeller Center, N. Y. The product is 30 per cent lighter than conventional electric wire and consists of a layer of glass fiber covered by fire-resistant synthetic rubber over the conductor. Overall diameter is 15 per cent smaller than conventional aircraft wire. The new wire, known as Neolay, is said to be highly resistant to oil, chemicals, mildew and fungus.

Fluid Condenser

NEW FLUID type variable condenser utilizing cams rather than plates is now available from the Timing Instrument Co., 106 Spring St., New York 12. The new type

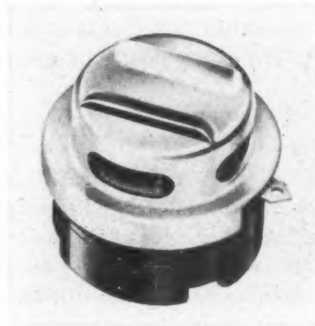


condenser, which is interchangeable with standard RMA types, is designed around a solid-barrel type of cam rotor having precise areas and contours. Rotor is mounted on low-loss plastic shaft separated from the single-unit solid stator by fixed clearance increments. Owing to the simplicity of the solid-mass construction and the inherent characteristics of the fluid dielectric, electrical efficiency is said to be twice that of air-gap multiple-plate condensers, and passage of much higher frequencies and power is possible.

Utility Power Pump

SMALL ENOUGH to hold in the hand, Simer paddle pump manufactured by the Jerome Simer Co., 422 Stinson Boulevard, Minneapolis 13, produces pressures up to 70-ft head, of which 20 ft may be suction head. Of interest to those designers concerned with relatively low capacity pumps for such materials as coolants or chemicals, this pump is said to take any chemical excepting those reacting on tire tread rubber, bronze or stainless steel. The unit is made of a metallic housing, ordinarily bronze, and an elastic, rotating impeller.

Thermostat



SMALL, COMPACT thermostat for general application at 120 to 140 volts ac, and designed to meet the requirements of Underwriters' Laboratories, has recently been announced by Cam-Stat, Inc., 2037 South La Cienega, Los Angeles. The unit is 1 9/16 inches in diameter and 1 7/32 inches in depth, and has a current capacity of 1500 va without the necessity of a condenser. A wide selection of temperature ranges from 50 to 350 F, low differentials and resistance to vibration are features of the instrument. Units are useful for many applications such as water heaters, furnace controls, furnace fans, etc. They are made of aluminum and plastic.

Fire Extinguisher Flood Valve

VERTICAL FLOOD VALVE with two types of discharge and control heads has recently been announced by Walter Kidde & Co. Inc., 675 Main St., Belleville, N. J. Identified as Kidde cylinder valve Model 4450, the unit is used with carbon dioxide cylinders and is said to adapt fire fighting to any special requirements. It meets such demands as remote and local operation of single, multiple or several cylinders simultaneously. The unit consists of a main discharge section and a control port section both of which are normally sealed by pressure of the gas in the cylinder. Both of the discharge heads contain a piston which, when depressed, opens the main discharge port of the cylinder valve. Operating force for depressing the piston is provided by admitting gas under pressure into the space at the top of the discharge head above the piston. Method of admitting gas depends on type of discharge head and layout of installation.

Permanent Magnets

TRAMP METAL extracting magnets have been announced by the Homer Mfg. Co. Inc., Lima, Ohio. The new units, known as Homer Triple-Air-Gap permanent magnets, have been designed for use with all types of free-flowing solid or fluid materials from which tramp iron or steel must be extracted. The new series of magnets is built in six standard sizes and is adaptable therefore to a variety

of processes. The magnets exert a 12-lb pull on a one-inch annealed steel ball at an angle of 45 degrees, are extremely compact and require very little space for application. Cast aluminum frame makes it possible to attach the magnet to any equipment without the use of insulating materials.

Electronic Timer

AUTOMATIC TIMER for intervals from 1/20-second to four minutes has been recently announced and is identified as Photoswitch electronic timer Type 30HL1. The unit is particularly recommended for process control and machine timing when long-life, repeat-cycle operation, or precise accuracy is required. It provides four basic types

of timing: Interval, delayed action, automatic repeat and programming, as well as many variations of these four types. In addition, a maximum time-interval selector switch provides for five time intervals. Variation in accuracy is less than 2 per cent. The unit employs only one vacuum tube and one relay, operates on standard 60-cycle voltages and provides an output current of 10 amp at 115 volts. Manufacturer is Photoswitch Inc., 77 Broadway, Cambridge 42, Mass.

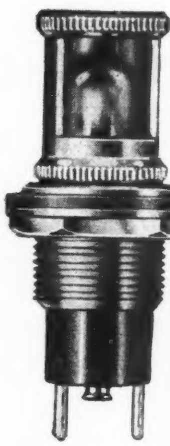
Carbon Brushes

HIGH SPEED carbon brushes identified as the 8800 series are a recent addition to the line of high-speed electrographitic brushes made by the Morganite Brush Co. Inc., 3302 48th Ave., Long Island City 1, N. Y. The new series has been developed to meet the trend toward higher peripheral speeds of motors and higher current densities. Their open texture permits close contact with the commutator thus insuring efficiency of collection and riding stability. Three grades are available: Link EG/8870, EG/8880 and EG/8866.

Starter-Generator

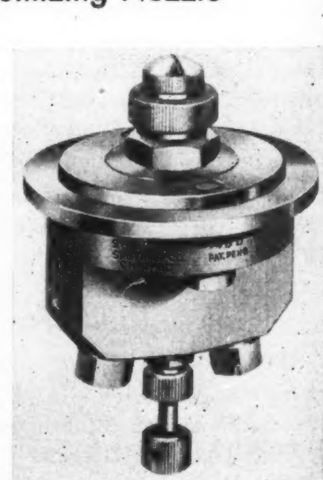
DIRECT DRIVE, light-weight combination starter-generator for aircraft, marine and automotive engine applications has been announced by the Electrical Engineering & Mfg. Corp., 4606 Jefferson Blvd., Los Angeles 16. Starter and generator are combined in one unit, the same winding serving both. The starter gear reduction for cranking is 23 to 1, the generator reduction is 2 1/2 to 1. Maximum starting torque is 160 ft-lb, and the generator output is 500 watts, continuous duty. A torque-limiting switch built into the unit prevents damage from backfire under all conditions. Coupling to the engine crankshaft eliminates need for belt or chain drives. Adapter mounting brackets are available for the most popular makes of engines.

Pilot Light



SERIES OF pilot lights designed on the light-shield principle, directing a beam of light within a rotation of 360 degrees, is now available. Light beam may be directed at any desirable angle by a turn of a knurled head of the unit. Series is available in four models with openings ranging from 1/2 by 1/2-inch to openings of 1/2 by 3/32-inch. Overall size of the unit is one-inch diameter by 2 1/4 inches long. A basic design feature of the series consists of a built-in resistor for use in conjunction with NE-51 Neon lamps on 110 and 200-volt circuits. Other features include heavy molded bakelite sockets, rugged construction, simple one hole mounting. Pilot light assemblies can be supplied complete with proper Neon Glow or miniature incandescent lamps of any required voltage. Manufacturer is the Dial Light Co. of America, Inc., 900 Broadway, New York City.

Pneumatic Atomizing Nozzle



ATOMIZING nozzles having features of removable mounting flanges and Monel strainers are announced by the Spraying Systems Co., 4023-F West Lake St., Chicago 24. Nozzles are useful for atomizing liquid pneumatically by means of either air, gas, or steam pressure. Water, oil, and liquids with similar viscosities may be sprayed. To prevent clogging of the nozzle orifice, core assemblies with fine mesh Monel-metal screen are installed in both the air and liquid intake chambers of the nozzle body, screens being removable for easy cleaning. Nozzles are available built of either white-

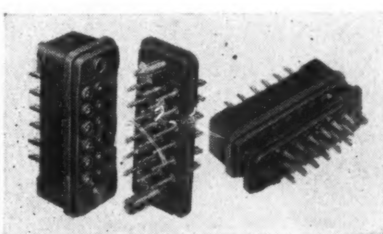
plated brass or stainless steel regardless of nozzle body and core material and shut-off needle is made of stainless steel. Installation of the nozzle consists of removing the flange from the nozzle and mounting the flange on equipment where required. After the flange is positioned, nozzle is bolted to flange. In this manner installation is simplified, yet rigidity is provided.

Automatic Timer

COMBINATION time counter and timer of a new type has been announced by the Electric Tachometer Corp., Broad & Spring Garden Sts., Philadelphia 23. The unit, known as Type PTT-1, is designed for accurate measurement and control of timed intervals and simultaneous operation of associated apparatus. Counter registers, in figures, time intervals up to 100 minutes with an accuracy of 0.001 minute. Operation is automatic for intervals of 0.1 and 1 minute, and manual for other periods of time. Automatic operation is obtained by means of a precision timer which starts and stops the counter. A double-pole double-throw relay is incorporated to operate valves, counters, recorders, etc., during the timing period. Instrument requires minimum of 10 watts 60-cycle power, has dimensions of 5 1/2 inches in height and 8 inches in width.

Multiple-Contact Connector

SELF-SEPARATING connector recently announced eliminates prying and pulling required to disengage ordinary multiple-contact connectors. The unit, manufactured by the Winchester Co., 6 East 46th St., New York 17, has an exclusive wiping action and spring-loaded contact



making either contact or separation smooth, easy and instantaneous. The new switch is molded of melamine plastic with one-piece inserts reducing the danger of flashover caused by moisture and dust accumulations. Connector may be supplied with a simple self-contained locking device for applications with very close space limitations, thereby eliminating the necessity for external clamping arrangements. Unit is available in two sizes: 18-contact Code No. QRE18, and twelve-contact Code No. QRE12. It is also available with conventional straight type contacts.

Packing Rings

V TYPE packing rings said to eliminate the tendency to weaken and split at the hinge have been announced by Greene, Tweed & Co., Bronx Blvd. at 238th St., New York 66. Known as Palmetto Pyramid Packing the new product is available in molded ring form made to exact dimensions. Bottom ring is installed first to receive the full impact of the pressure on power stroke. The ring expands wedge-shaped lips of each ring above so that the packing is pressed against both rod and side walls, effectively preventing leakage. Binding is prevented by infiltration of fluid be-

tween the rings and storage of fluid in the arrowhead reservoir. Ease of operation is assured by the curved design of the interior lip surface which also prevents friction within the packing. On the return stroke, lessening of pressure permits the built-in restitutional property of each ring to exert itself, thereby enabling the rings to instantly spring or contract to normal. No special adapter ring is required since the top ring has a flat surface and 45-degree angle surfaces that accommodate any standard shape gland-follower.

Contact Alloy

DEVELOPMENT OF a versatile new silver-molybdenum alloy called Callinite Type SM has been announced by the Callite Tungsten Corp., Union City, N. J. The new material is particularly suitable for facing of contact surfaces in switch gear designed to handle heavy currents. The alloy is a high conductivity facing material suitable for high-current applications where pitting, sticking or welding of contacts occurs. The new alloy is available in three grades having densities of approximately 10.3 grams per cubic centimeter, rockwell B hardness 60 to 90, and conductivity ratings of 45 to 60.

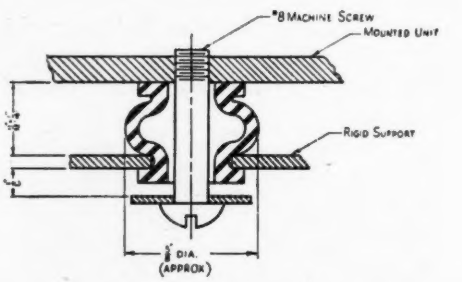
Midget Solenoids

SOLENOIDS of small size yet having high force characteristics are now being manufactured by John S. Barnes Corp., Rockford, Ill. The units have a hold-in pull between 13 and 15 pounds, and a pull of 4 to 7 pounds

when the plunger is extended between ¼ and 1⅛ inches. At 110 volts the inrush current is approximately 5 amperes, and the holding current ¾ ampere. The unit measures 2 3/32 inches high, 3 7/16 inches long and 2⅛ inches wide. Types are available for either ac or dc operation and either push or pull application.

Vibration Insulators

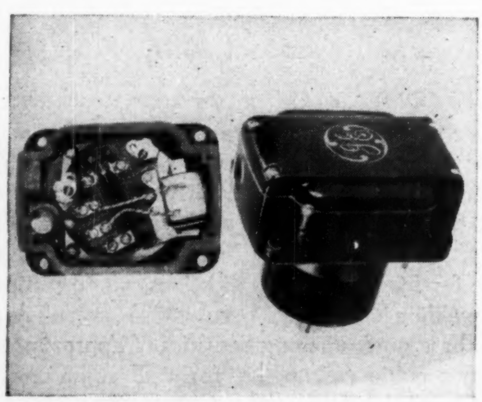
LIGHTWEIGHT vibration isolators of rubber flexure type are now available. The units are ½-in. outside diameter and ⅝-in. high and support loads ranging from 5 oz



to 3 lb. Known as Type 275 the units will isolate vibration frequencies as low as 15 cps with resonances as low as 9 cps. Manufacturer is L. N. Barry Co. Inc., 179 Sidney St., Cambridge 39, Mass.

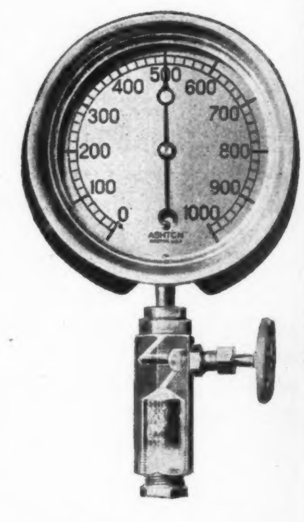
Dus'proof Plugging Switches

LINE OF OILTIGHT and dustproof plugging switches for flange and surface mounting recently has been announced by the Control Division of the General Electric Co., Schenectady. The new type switches are designed to remove plugging power from a motor at the correct moment and thus keep the motor from restarting in reverse direction. Maximum continuous rotating speed



of the new switches is 1800 rpm, while two sizes o' springs provide for adjustment of contact operating speed over ranges of 40 to 140 rpm, and 140 to 750 rpm. Contacts in new switches are silver and handle directly coil current of 150-ampere contactor thus eliminating cost of interlocking relays. New switches are provided with greased-packed ball bearings for operating the shaft and magnet assembly. Alnico magnet assembly with its operating arm provides the force for operation of the contacts without the use of frictional parts or clutches, thereby reducing maintenance. A lockout device can be provided to release the lockout latch and permit normal operation of switch when the motor is connected to the line. On applications which require that the driven machine be turned over by hand, the lockout device protects operator by acting as a guard against accidental starting.

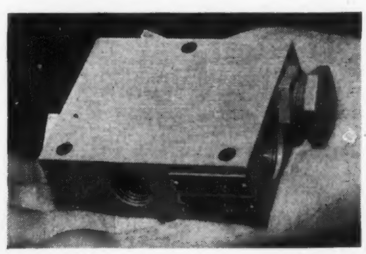
Pulsation Damper



APPLICABLE TO gages and governors is the new pulsation dampener announced by the J. A. Campbell Co., 645 East Wardlow Rd., Long Beach 7, Calif. The new unit, known as the Micro-Bean, is available in all-brass and all-steel construction with stainless steel stem. The unit eliminates scoring resulting from high fluid viscosity, by providing a screw which when turned slightly brings seating back to perfect control. After heavy scoring, the unit can be restored to good condition by opening and closing the valves ten times. Micro-bean is stocked in three pipe-thread sizes—1/4, 3/8 and 1/2 inch—for pressures up to 6000 pounds. It can be used on any gage line to boilers, engines, etc.

Hydraulic Valve

LOW COST HYDRAULIC cut-out valve of small size and few moving parts has been announced by Electrol, Inc., 85 Grand St., Kingston, N. Y. The unit is available with cut-out pressures from 300 to 1500 psi and variable differential pressure from 75 to 500 psi. Three of the ports are 3/8-inch female national pipe thread. The fourth is



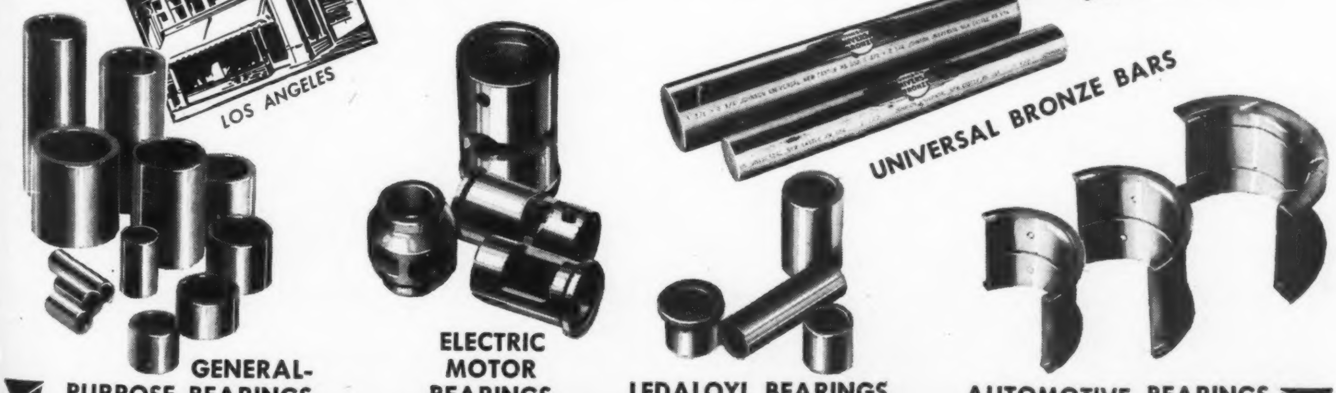
a 1/8-inch national pipe thread bleed port. Each of the positive seating valves is designed for maximum efficiency in performing its specific function. One valve is

MANUFACTURERS like to depend on Johnson Bronze for their Sleeve Bearings because of the quality product and our friendly, convenient service. It makes little difference where you are located, you will find a factory trained Johnson Bronze man *as near as your telephone.*

On bearings made to your specifications he is ready, willing and capable to answer your questions regarding the various types and their proper use. For replacement, he places at your disposal complete stocks of automotive and industrial bearings, electric motor bearings, UNIVERSAL Bronze Bars, and Babbitt. Or he will gladly give you the name and address of your local Johnson Distributor.

Isn't this the type of bearing service you can use? Why not plan now to depend on Johnson Bronze? Take full advantage of our more than forty years exclusive bearing experience. Remember, that only Johnson Bronze makes *every* type of Sleeve Bearing.

JOHNSON BRONZE COMPANY
525 S. MILL ST. ——— NEW CASTLE, PA.

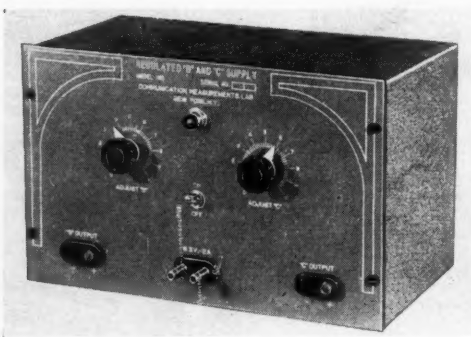


EVERYTHING YOU NEED IN *SLEEVE TYPE BEARINGS*

the ball-and-seat type, another is the cone-and-seat type, and the third is the O-ring-and-flapper type. Unit measures 1 1/4 inches deep and 2 3/4 by 3 1/2 inches respectively in width and length. All four ports are in the same plane.

Dual Power Supply

TWO INDEPENDENT, regulated power sources are combined in one unit in the CML 1115 dual power supply recently developed by Communication Measurements Laboratory, 120 Greenwich St., New York. The "B"



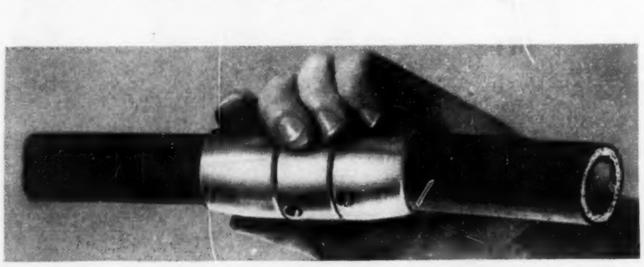
supply furnishes a dc voltage variable from 180 to 300 volts, 70 ma, and the "C" supply furnishes a dc voltage variable from 9 to 75 volts. Maximum ripples are 25 mv and 7 mv for the "B" and "C" supplies respectively. Panel controls are provided to adjust the output voltages throughout the ranges indicated.

Rust Preventive

IMPROVED RUST PREVENTIVE for ferrous parts, useful between operations and for storage, has been announced by Oakite Products, Inc., 22 Thames St., New York. The new preventive, known as Oakite special protective oil, imparts a thin transparent protective coat to parts. Because of its water displacing properties the oil can be applied to parts immediately after cleaning and rinsing while they are still wet. The coating is said to have found many uses in plants where temporary or semipermanent surface protection is desired.

Hose Coupling

SMALLER, LIGHTER, streamlined hose coupling recently has been announced by the Bar-Way Mfg. Co., Stamford, Conn. The coupling has been tested for ten years



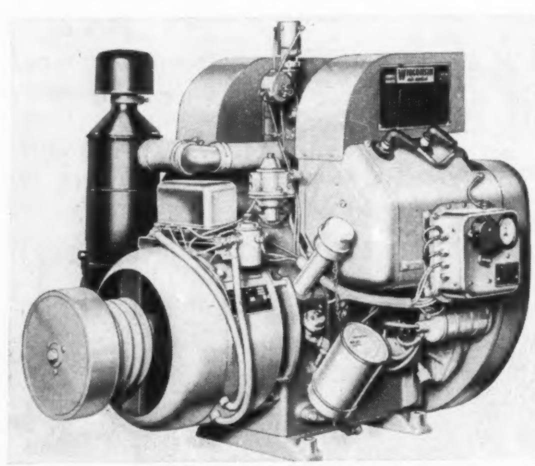
and is designed for working pressures in excess of 1000 psi. It weighs 1/3 less than any comparable unit and, in the popular size—1/2 inch—is 3¾ inches long with an overall diameter of 1 3/8 inches. Of bronze castings, its streamline design eliminates any obstructing projections and dangerous sharp edges. The unit is available in 1/2, 3/4 and 1 1/4-inches sizes.

Protective Plastic Covering

DURABLE plastic which may be shrunk upon wires, handles, etc., has been announced by the General Electric Co., Pittsfield, Mass. Available in cap and sleeve form in diameters up to one inch, it is soaked in a dilator solution and then placed upon the part for shrinking. The covering shrinks to smaller than its original size to form a tight covering over the exposed surface. Plastic employed is said to be exceptionally tough when in the swollen state and will not split when applied. It will shrink tight over widely varying diameters and shows no tendency on accelerated aging tests to become brittle and split after exposure for long periods in hot dry atmosphere. In addition, it possesses excellent heat resistance and is unaffected by common solvents and acids encountered in production plants.

Compact Power Plant

GENERATOR SET serving as a convenient power source recently has been announced by the Wisconsin Motor Corp., Milwaukee 14. The unit consists of a V-type, four-cylinder gasoline engine direct-coupled to a combination 12-volt electric generator and starting motor. The generator frame bolts direct to engine crankcase, and the outer end of the generator shaft carries a free-wheeling, centrifugally-operated V-belt sheave so that the engine will be relieved of load in starting. Starting is fully automatic,



controlled by a thermostatic switch which operates through a control box on the engine. The direct-connected generator and starting motor eliminates a spring drive starting pinion, an important feature where frequent starting is necessary. Engine is air cooled and suitable ducts are provided to carry away hot air.

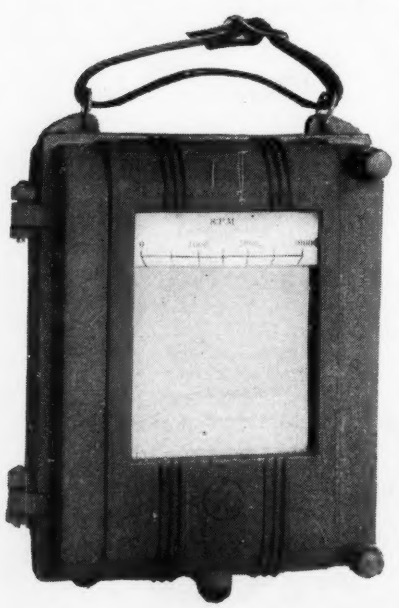

PACKINGS
PLUS!
Whether you require leather, fabricated or homogeneous rubber packings, Houghton can furnish them, in every style and size.
The underlying reason for Houghton packing leadership is in its engineering aid given to design and maintenance men. We realize that to make better packings is not enough. They must be carefully chosen, and the design must be right for the service. That's why men come to Houghton for better packings, properly recommended. Have you a packing problem?
E. F. HOUGHTON & CO.
303 W. Lehigh Ave., Philadelphia 33
VIM Leather and

engineering dept equipment

Fluorescent Lamp Resistors

PLUG IN type resistors for use with single lamp portable fluorescent lamp fixtures operating on direct current are now being manufactured by the Ward Leonard Electric Co., Mount Vernon, N. Y. The new resistors, identified by Bulletin 26, are of the wire-wound type mounted in a small perforated metal enclosure. The unit, measuring 1 5/8 inches in diameter and 1 13/16 inches in height, incorporates spring pressure prongs on one end and a receptacle on the other. Resistor is plugged in between the lamp fixture and the direct current outlet for use with single fluorescent lamps up to and including 20 watts.

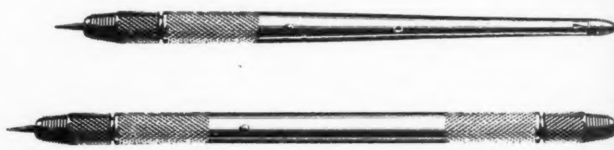
Tachometer Recorder



LIGHTWEIGHT inkless tachometer recorder to provide records of rotating speeds has been announced by the Meter & Instrument Division of the General Electric Co., Schenectady 5. The unit, which is known as Type CF-3, has been designed to operate with an aircraft type alternating current tachometer generator although suitable for use with ac generators having proper characteristics. The instrument has a scale range of 0 to 3000 rpm and should be used for the range 600 to 2500 rpm. Readings are accurate to within 1.5 per cent of full scale with full-scale deflection obtained in two seconds, and the record is made on a 4-inch wide record roll by means of a typewriter ribbon. Standard chart speed is 3 inches per hour with modification of speed possible by additional rate gears changing speed to 1 inch per hour, 2 inches per hour, or 1 inch per day. Dimensions of the recorder are 5 11/32 by 8 1/16 by 10 9/16 inches, and weight is 12 pounds. Splashproof and weatherproof case is an aluminum-alloy casting employing a pressure gasket.

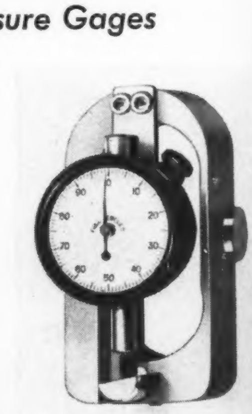
Drafting Pencil

ALUMINUM DRAFTING PENCIL known as the Elastichuck recently has been announced by the Elastichuck Sales Co., Box 220, Inglewood, Calif. The pencil features a rubber collet in the neck of the chuck, gripping the lead and cushioning it against undue pressure so that breakage of lead is greatly curtailed. The rubber collet is the only contact between lead and pencil. However, the



pencil is so designed that a hardened steel chuck protrudes from the tip of the pencil, protecting the pencil when sanding against file or pad. Chuck is knurled to facilitate gripping pencil. The new pencils, which use all standard drawing leads, are available in single or double-end types.

Mechanical Pressure Gages

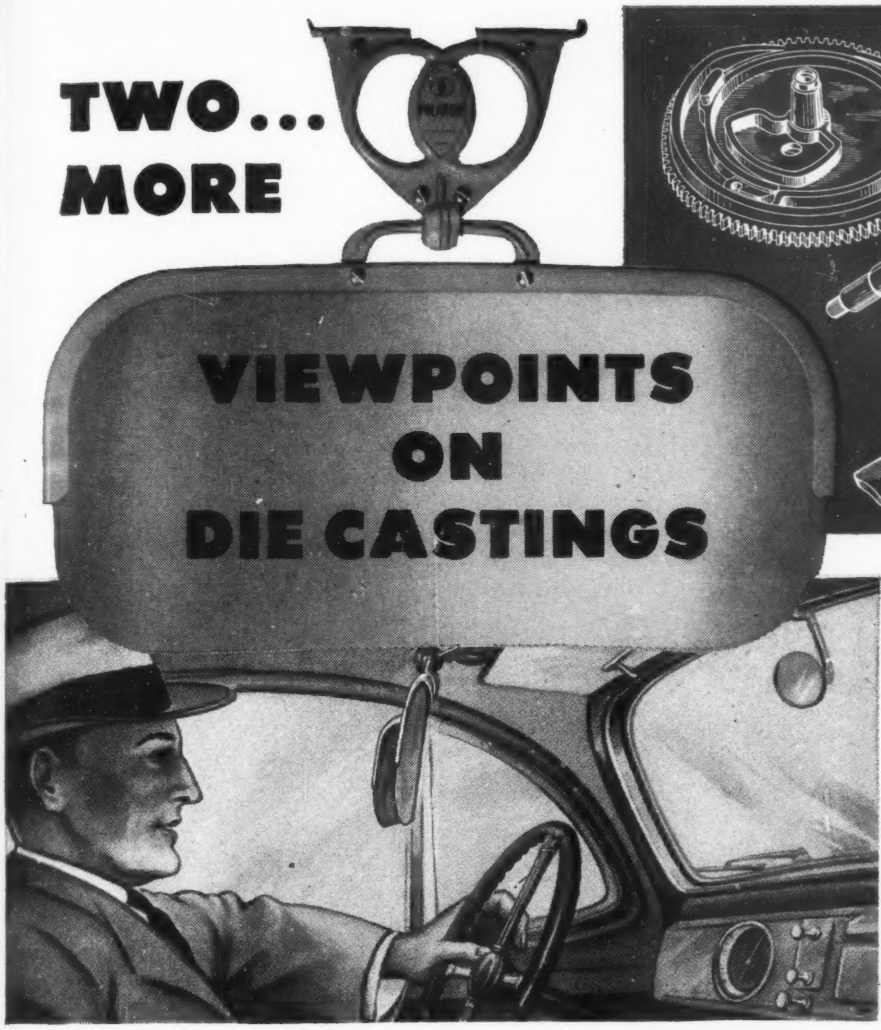


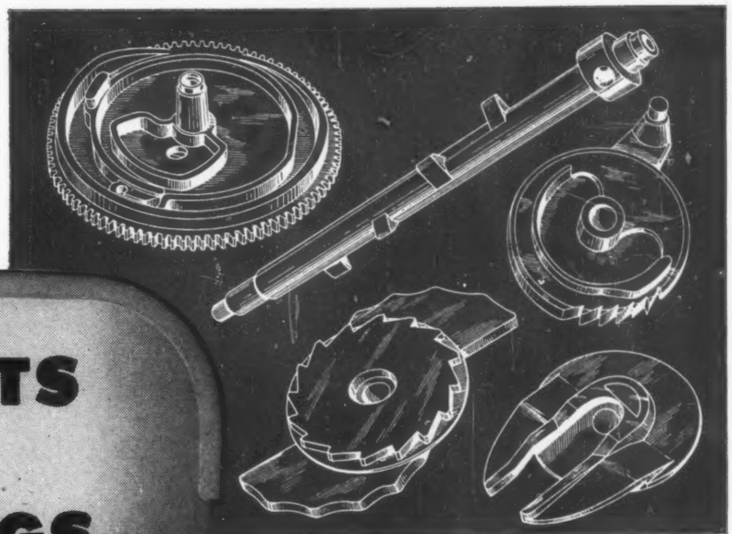
MECHANICAL PRESSURE gages having a gross weight of only 2 1/2 pounds yet capable of measuring pressures to 5000 psi have been announced by W. C. Dillon & Co. Inc., 5410 West Harrison St., Chicago 44. The units, which use the beam-deflection principle, occupy a maximum space of only 2 3/8 inches in measuring position. Six models are available in pressure ranges to 5000 psi.

Fluorescent Troffers

FLUSH TYPE recessed fluorescent lighting troffers have recently been announced by the Edwin F. Guth Co., 2615 Washington Blvd., St. Louis, 3. Special knock-outs in the ends of the troffers make possible accurate 48-in. lengths. Lampholders may be inset in the ends so that they are flush with the outside surface of the closed ends,

TWO... MORE VIEWPOINTS ON DIE CASTINGS





COMPLEX CAMS ARE DIE CAST—IN ONE PIECE

Die castings offer extraordinary flexibility of design in producing pulleys, wheels, gears, ratchet elements, cams, etc. Consider, for example, the various types of *zinc alloy* die cast cams in the drawing above. Even track cams are readily die cast to size and there are numerous cases in which two or more cams, aside from such other parts as gears, bosses, pivot pins, stops, ratchet teeth and the like, are produced as integral parts of one casting. Important savings in machine work are realized when intricate cams are die cast to correct contour, for then they do not have to be machined individually.

In die casting the precision work is done on the die, and the thousands of castings produced in it have only minute variations in essential dimensions. If possible, cams which must be held within close dimensions should be so designed that, in die casting, flash will not occur on the working face or faces. This eliminates the possibility of affecting the accuracy of these surfaces in the flash removal operation.

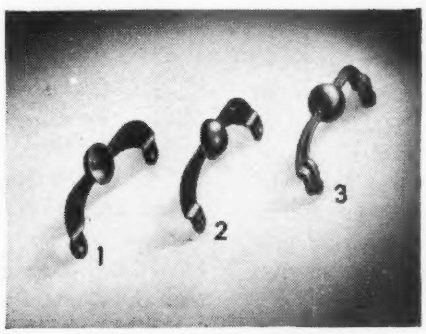
For additional data on die casting design ask us—or your die casting source—for a copy of the booklet shown below.

A POINT OF ECONOMY—ON A SUN VISOR

The polarizing sun visor pictured above and below is designed to be slipped over the visor which is standard equipment on all automobiles. The bracket for this visor features a universal joint type of construction to permit the visor to be flipped up out of the way when not needed. It is used for day driving only—to screen out disturbing reflected sun-glare.

As shown in the photograph at the left below, just two different *zinc alloy* die castings are required in this assembly. By mating a pair of the thin-sectioned bracket castings, both a channel for the wire visor clamp and a socket to house the ball on the shaft casting are formed. In the original design, the ball shaft was assembled by copper-brazing two mating stampings (#1 and #2 in the photograph at the right below). Conversion to a one-piece *zinc alloy* die casting (#3) eliminated this extra assembly operation and resulted in a stronger unit.

Does this die cast assembly suggest a means of solving a design problem or cutting production costs in *your* products?



Send for your copy

ZINC

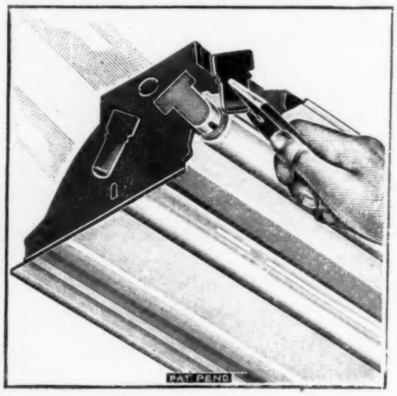
FOR DIE CASTING ALLOYS

The New Jersey Zinc Company, 160 Front St., New York 7, N. Y.

The Research was done, the Alloys were developed, and most Die Castings are based on

HORSE HEAD SPECIAL (99.99 + % Uniform Quality) ZINC

The troffers, therefore, are the length of the fluorescent lamps and their lampholders, providing more efficient use of space and light. A complete choice of accessories available with the units includes baffles, louvres, and flat



and formed-glass panels. Two reflector surfaces, 300 degrees white, and alzak, are available. Troffers are available in two types: Deep types for 1, 2 or 3 forty-watt lamps, and shallow types for 1 or 2 forty-watt lamps. Both types are supplied with flange or tee-bar mounting edges. The recessed troffers are complete units ready to install.

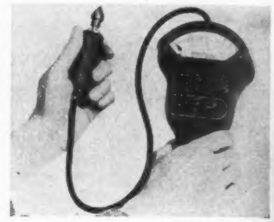
Variable Transformer

A NEW 10-amp Variac to fill the gap between the conventional 5-amp and 20-amp adjustable autotransformer has been announced by General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass. The 115-volt models are rated at 10 amp with a 15-amp maximum coinciding with the capacity of commonly used outlets, plugs and lines. Units are designed for the most favorable distribution of copper and iron, with low-loss core material and lightweight structural parts. This new type Variac is said to deliver from 60 to 100 per cent more KVA per pound than older models. Output voltage of the new Variac may be varied from zero volts to 17 per cent above line voltage. They are available in 6 models, covering 115 and 230-volt service to suit the various mounting requirements of the users.

Resistor Selector

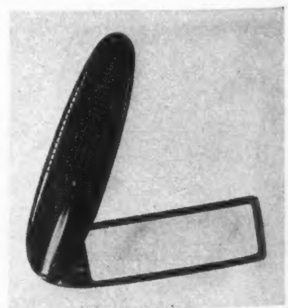
CARD TYPE of resistor selector is now available through the Allied Radio Corp., 833 West Jackson Blvd., Chicago 7. Used for determining resistance values for particular color codes or vice versa, this selector consists of three rotary disks mounted in a cardboard case. The disks are provided for setting code colors and corresponding resistance values are brought into alignment automatically. Card includes data covering resistances, tolerances and complete listing of RMA-JAN 10 per cent resistor stock values. The unit saves time and errors.

Low-Speed Tachometer



INSTRUMENT for direct measurement down to 10 rpm and 1 fpm is the new Metron low-speed hand tachometer Type 25B. The instrument has three ranges: 10 to 200 rpm, 20 to 400 rpm, and 50 to 1,000 rpm. Similar in appearance to the standard type 25A tachometer manufactured also by Metron Instrument Co., 432 Lincoln St., Denver 9, this instrument is inherently sensitive to low speeds and does not employ gears or require the use of speed reducing adapters to measure these speeds. The instrument consists of two units—the head which is normally held in left hand, when making measurements, and the indicating unit. Finger-tip control is provided on the indicating unit so that the speed range can be changed easily with the thumb of the right hand while making a measurement. Speed range may be varied while the tachometer head is engaged with the rotating shaft. The instrument is not a generator but a double-pole, double-throw switch connected in a series circuit consisting of a battery, a condenser and a milliammeter. Oscillation of the switch blades alternately charges and discharges the condenser by means of the battery, permitting current to flow in small charges through the milliammeter. The circuit is so designed so that the current is exactly proportional to the rpm of the spindle. The tachometer has an accuracy of 1 per cent of full scale and is ruggedly built for sustained accuracy. The head contains only one rotating part which is mounted in ball bearings.

Magnifying Glass



ANNOUNCED by the Edroy Products Co., 480 Lexington Ave., New York 17, is a new type of hand glass known as the Longview Magnifier. This magnifier has a long rectangular lens enabling one to read fine print and observe detail over large areas. Measuring 4 inches overall, the 3½-inch lens folds into its Lumarith case when not in use. Magnification is 2½ times. Rectangular type of lens makes it possible to reach long lines of print at a glance.

Ever since the advent of the "silent" timing gears for cars, laminated material for gears has become essential where quiet operation is required.

But silence is only one of the many advantages. Gears made from Lamicoid laminated plastic require practically no lubrication. They absorb abrasive dusts and small metallic particles that often cause excessive gear wear on metallic combinations. When gears made from Lamicoid are run in combination with steel or cast iron, their life is usually longer than that of metallic gears. Their strength is comparable to that of cast iron.

Lamicoid is made of selected cotton fabrics laminated with special resins to meet various conditions. This combination makes for silent, smooth-running gears that can be blanked out or machined to remarkably close tolerances, permitting accurate pitch or openings close to rim.

Standard-sized sheets are 36 by 42 inches. Ask your regular gear cutter for Lamicoid gear stock or write our sales offices or fabricators listed below about your requirements.

MICA INSULATOR COMPANY

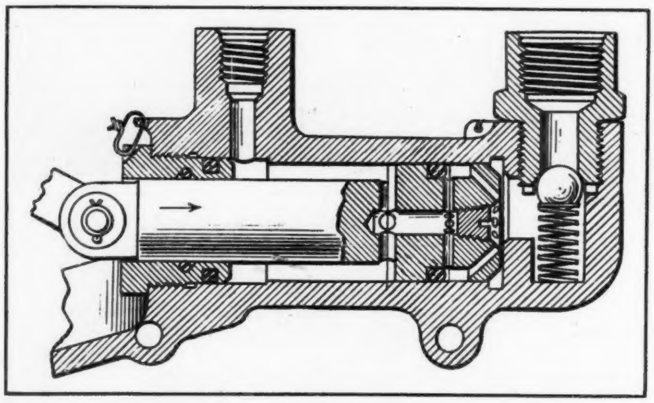
Dept. 20, Schenectady 1, N. Y.

SALES OFFICES: Boston • Chicago • Cincinnati • Cleveland • Detroit • New York • St. Louis • Philadelphia • Rochester • Western Fiberglas Supply, Ltd., San Francisco 7, California, and Los Angeles 15, California

FABRICATORS: Lamicoid Fabricators, Inc., Chicago, Ill. • Insulating Fabricators, Inc., Watertown, Mass. • Insulating Fabricators, Inc., New York City • Bakoring, Inc., Houston 10, Texas

Noteworthy Patents

COMBINATION PISTON-VALVE design covered in patent 2,404,547 simplifies manufacture, assembly and servicing of auxiliary hand pumps for aircraft hydraulic systems. Assigned to Adel Precision Products Corp. by Carl J. Strid, the valve arrangement utilizes a standard O-ring seal to serve both as seal between the piston and

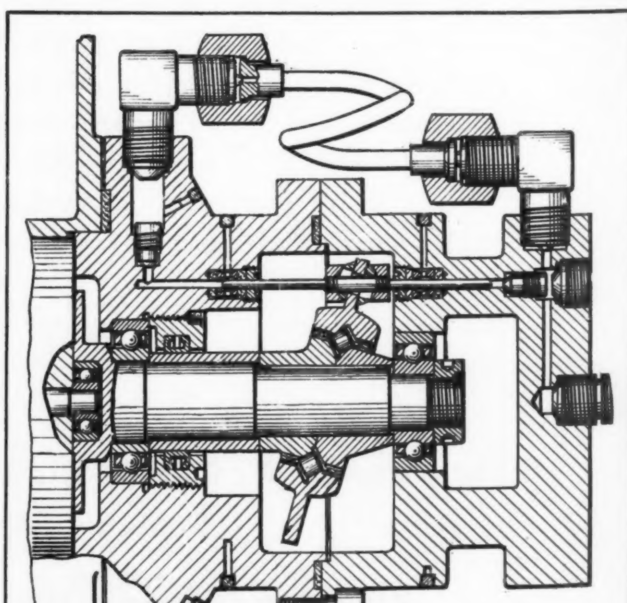


cylinder and as a check valve. By employing an enlarged sealing ring groove in the piston and arranging ports through the piston head, on one stroke the sealing ring moves to a position opening the ports for passing fluid through the piston and on the other stroke moves to a position closing the ports. Conventional separate check valving ordinarily required is thus eliminated along with attendant servicing.

INCREASED EFFICIENCY of worm and sector drives is achieved by a new design of antifriction ball worm gear covered in patent 2,404,378 assigned to the Cleveland Pneumatic Tool Co. by Henry S. Hoffar. Intended primarily for automotive steering mechanisms, the unit allows for complete removal of backlash and is so designed as to avoid frictional contact between load-carrying balls by utilizing smaller spacer balls to separate them.

INTEGRAL VALVING, designed to eliminate the necessity for stuffing boxes or other sealing means in connecting control-valve pistons to a reciprocating fluid motor is covered in patent 2,405,949. Assigned to Gilbert & Barker Mfg. Co., by Alfred L. Grise, the design utilizes a dual piston—two interconnected axially-spaced pistons of different diameters—to provide an intermediate open area for attaching the control valve. Control arm of the valve extends inward to provide automatic actuation by attachments on the piston arm.

THREE-WAY ANTIFRICTION BEARINGS, taking forces radially as well as in opposite axial directions, makes possible a greatly simplified swashplate type hydraulic pump capable of delivering 30,000 psi and greater pressures. Reciprocating power, being delivered to the nonrotating swashplate through the three-way bearing has two-way axial components which are utilized to effect power and suction strokes of double-acting plungers operating on opposite sides of the plate. Pressure passages are provided in a unique manner in that drilled radial passages from each cylinder are interconnected by an annular groove machined in to meet the passages. Peripheral sealing of the groove is accomplished by a wire inlay



Your machine parts can be made at lower cost from J&L Cold Finished steel because it is uniform. This means faster cutting speeds, less tool wear for you.

At J&L, steel for cold finishing is made expressly for that purpose. The required quality and grade are specifically outlined when the iron is made in the blast furnace, converted into steel at the Bessemers or open-hearth furnaces and rolled into bars or special shapes. The long experience of Jones & Laughlin in the production of Cold Finished steel from the time the process was invented by them further assures the uniform quality of the product—a quality that will enable you to step up your production of accurate machine parts. Write for further information.

JONES & LAUGHLIN STEEL CORPORATION

PITTSBURGH 30, PENNSYLVANIA

welded into position. Patented under number 2,403,292 by William Messinger.

CONSTANT PRESSURE over widely varying changes in the speed of operation, is automatically maintained by a novel pump covered in patent 2,399,990. Assigned to United Aircraft Products, Inc., by Merlyn M. Culver, the unit is primarily designed for use as a fuel pump. Pistons of the pump, which float within a rotor member, accomplish their pumping action by contact with an eccentric. Set delivery pressure controls the eccentric to provide variations in delivery of fluid in accordance with variations in demand. Reversible, the pump includes a by-pass to relieve pressure during no-flow periods.

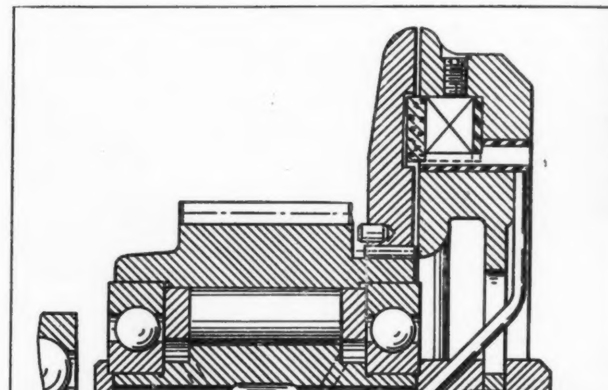
UNIFORM VELOCITY during a large part of the linear movement of a machine bed is achieved with a novel twin crank motion covered in patent 2,403,760 assigned to American Type Founders, Inc., by Frederick W. Seybold. Especially suited for use in reciprocating beds of cylinder printing presses, the crank arrangement provides uniform linear velocity exactly equal to that of the impression cylinder during the period of printing contact without periodic engagement and disengagement of the drive elements. The cranks utilized are disposed upon one side of a swinging lever with axes substantially perpendicular to that of the lever, are out of phase with each other and have different angular velocities.

EFFECTIVE BRAKING SURFACE of the brake disk utilized in the combined centrifugally operated brake and speed governor unit covered in patent 2,401,256 is doubled or possibly tripled by the use of grooves. Annular or circumferential grooves in the face of the magnetically disengaged braking disk deform the friction surface to provide the greatly increased braking effort and naturally allow use of elements of minimum size. Patent is assigned to Lear, Inc., by William P. Lear.

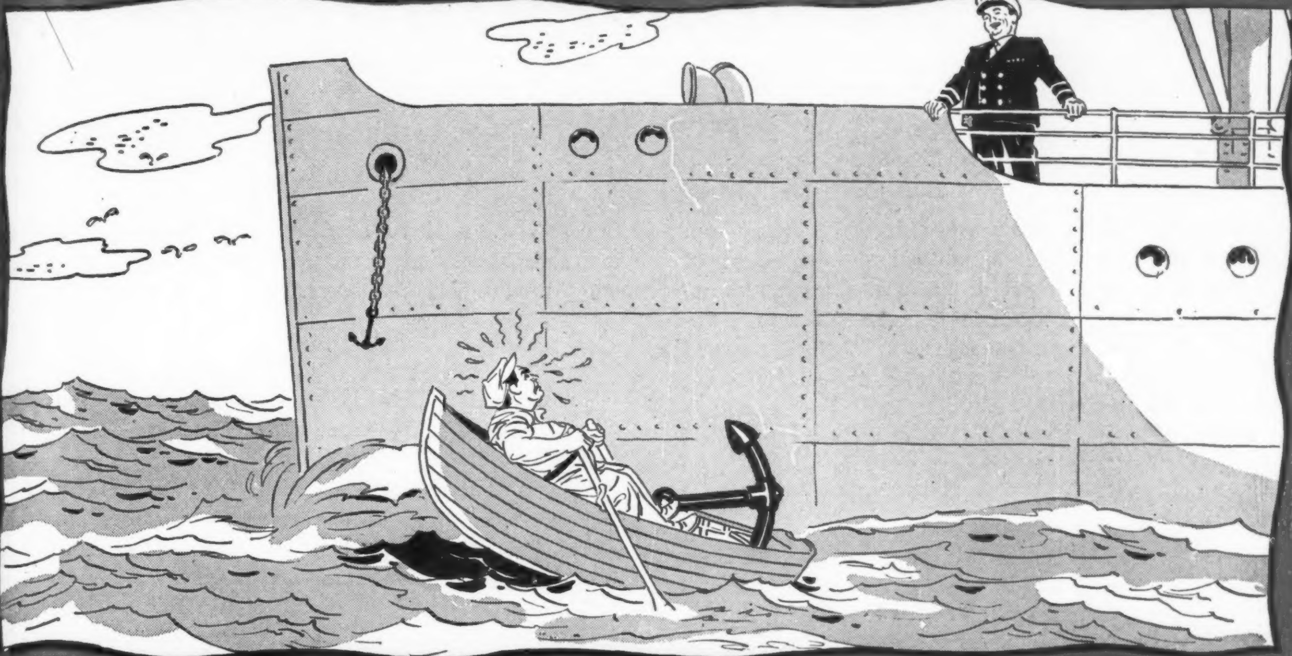
COMPLETELY SEALED so that operating mechanism requires no packings or other means of sealing off external moving parts, a solenoid valve designed for hydraulic systems permits "stacking" with but a single pressure and a single return connection. Assigned to Adel Precision Products Corp. as patent 2,404,349 by W. R. Brant and H. G. Chapman, this flow-reversing valve is spring centered and connection between the solenoid armature and the valve spool is by means of ball and socket joints to obviate misalignment.

HIGH EFFICIENCY over a wide range of speeds as well as an infinitely variable speed ratio over these speeds is achieved by a variable-speed drive covered in patent 2,400,306. Particularly adapted for driving an internal-combustion engine supercharger or cooling fan, the unit utilizes a number of hydraulic couplings in which the amount of fluid present is controlled by a helical-screw pump mechanism actuated by speed differences through a planetary gear system. To assure high efficiency, the couplings are operated only over a range of low slip.

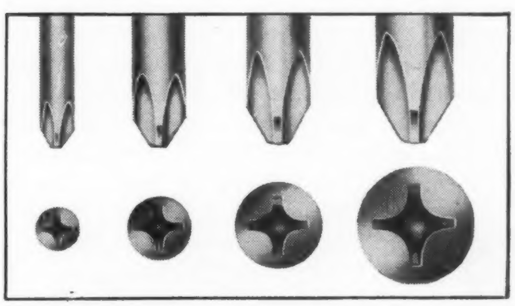
MAGNETIC OVERRUNNING CLUTCH covered in patent 2,400,625, is light in weight and compact and provides the means for transmitting power from one or more airplane engines to a propeller. Assigned to Lockheed Aircraft Corp. by John J. Bloomfield, the clutch allows for "windmilling" of the propeller and dropping out of one or more of the engines. Employing a mechanical one-way or sprag type clutch arrangement for normal transmission of power to a propeller, reversal or stoppage of the engine power shaft disengages the drive. To deliver full power in either direction when the mechanical clutch is inactive, a magnetic unit provides for direct engagement. The electromagnetic coil is unusual in that minimum size and maximum efficiency is obtained by utilizing as windings thin aluminum strip wound under tension.

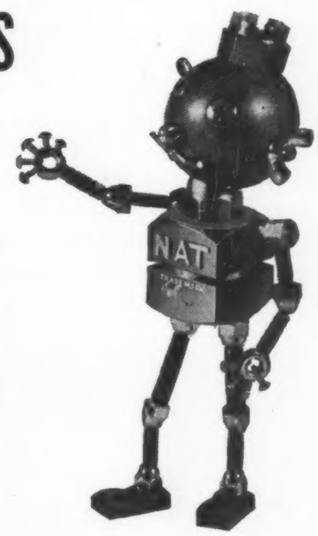


What's WRONG with this picture?



FOUR SIZES of drivers insure best results with the Engineered PHILLIPS RECESS





Phillips Recesses are designed for maximum driving power in each size of screw. Drivers are matched to insure proper torquing values.

There are only four drivers to cover the complete range of sizes, and two drivers fit 85 per cent of all Phillips Screws used.

With the correct size of driver you get all the advantages of recessed screws and avoid the "bugaboo", present in some recessed screws, of possible reaming. The great driving power of the cruciform recess makes this a real danger when you use too large a driver.

Conversely, too small a driver spoils the outstanding advantage which the recessed screw can give you—that same driving power.

We design delicate tools for the tiny screws and robust, sturdy tools where maximum torques are permissible. It pays to use the right tool for the job.

A ship's anchor is out of place in a rowboat!

National HEADED AND THREADED PRODUCTS

THE NATIONAL SCREW & MFG. CO., CLEVELAND 4, O.

MEN... of machines

M. D. STEWART, associated with the Oliver Corp. for twelve years, has been appointed chief engineer of the South Bend, Ind., plant of the organization. Immediately upon graduating from Purdue, he joined the company and did tractor engineering work. Later he joined the John Deere Tractor Co. and International Harvester Co. serving in a similar capacity. In 1937 he returned to the Charles City, Ia., plant of Oliver and was appointed chief engineer in 1942. During this time the Charles City plant had war equipment under way, such as tanks, naval landing craft and motor grader transmissions, in addition to tractors. Mr. Stewart grew up on a Southeastern Iowa farm and prior to entering Purdue he worked for one and one-half years in production at the Studebaker Corp.

ALFRED L. BOEGEHOLD has been elected president of the American Society for Metals at its recent annual meeting. Mr. Boegehold, a mechanical engineering graduate of Cornell, is head of the metallurgy department, Research Laboratories Division, General Motors Corp., with whom he has been associated since 1925. Immediately upon graduation, he was first employed at Remington Arms & Ammunition Co., and later at Bridgeport Brass Co. He then joined General Motors as research metallurgist and since 1925 has been head of metallurgy department of the laboratory. Mr. Boegehold is a past chairman of the Detroit Chapter of the society and was selected to deliver the Campbell Memorial Lecture before the ASM in 1938. He is also a member of the American Foundrymen's Association and the American Institute of Mining and Metallurgical Engineers.

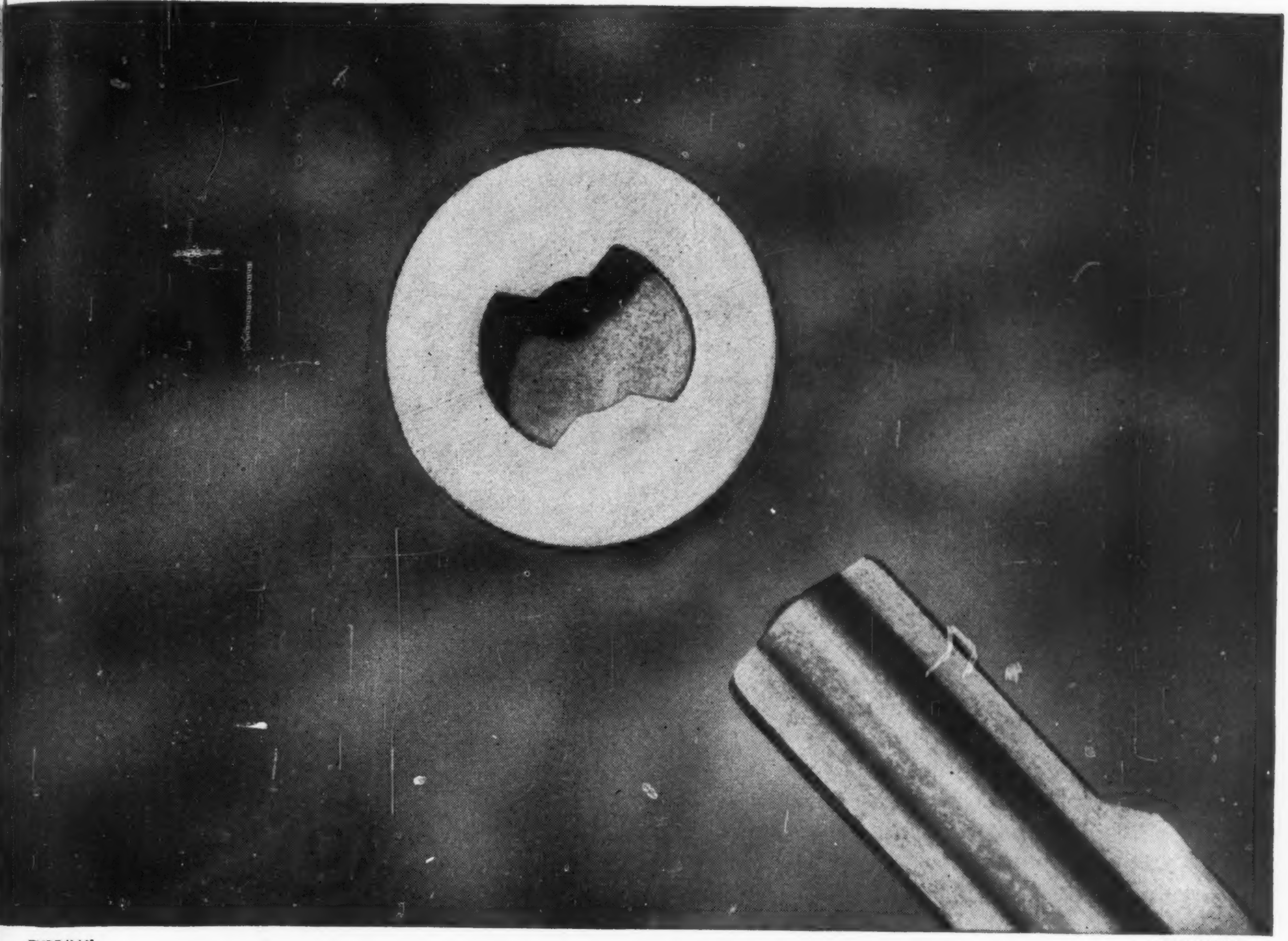
C. E. FRUDDEN, consulting engineer of the Allis-Chalmers Mfg. Co., Tractor Division, has been named the sole nominee for the 1947 national presidency of the Society of Automotive Engineers. Mr. Frudden, who has a long background of engineering experience, took his degree at Iowa State College with graduate work at Columbia. He has submitted research papers to the SAE and the American Society of Agricultural Engineers. In 1929 he joined Allis-Chalmers where he has been instrumental in effecting many advances in the tractor field during the past seventeen years. Prior to the war he was promoted from chief engineer of the West Allis Tractor Division to executive engineer of the entire Allis-Chalmers Tractor Division. Mr. Frudden is the first tractor man to be elected to the presidency of the society.

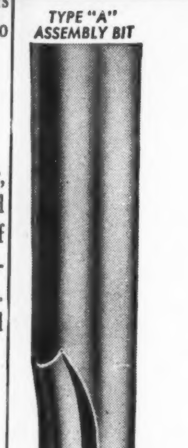
ASTOR L. THURMAN, formerly chief electrical engineer, The Aetna-Standard Engineering Co., has been appointed assistant to the vice president. Prior to becoming chief electrical engineer in 1945, Mr. Thurman had been connected with General Electric Co. for eight and a half years. JAMES RIDDELL replaces Mr. Thurman as chief electrical

M. D. Stewart

Alfred L. Boegehold

C. E. Frudden





TIME FOR A POST-MORTEM ON COSTS?

Let Clutch Head Users Furnish the Answers

Comparing CLUTCH HEADS with other recessed head and slotted head screws, they testify they have found:

Higher Visibility Cuts Cost 3 Ways . . . saving "break-in" period for new operators; substituting sureness for hesitation; inspiring higher speed born of confidence.

Chewed-Up Heads Eliminated by dead-center entry with the Center Pivot column, preventing driver canting and making straight driving automatic.

Slippage Hazard Reduced to Zero by CLUTCH HEAD's all-square driving engagement and absence of "ride-out" as set up by tapered driving with other type screws.

A Fatigue Factor Disposed Of because non-tapered driving lets the screw ride home without the application of exhausting end pressure to combat "kick-out."

Up to 214,000 Screws Driven continuously and without interruption for reconditioning by the Type "A" Bit . . . tool economy they describe as "unheard of."

The Lock-On Surmounts Hurdles of inside reaching by uniting screw and bit as a unit . . . in assembling and also in "un-buttoning" the job in the field.

Like to check these features? . . . then send for screw assortment and sample Type "A" Bit

Screwdriver Operation

for emergency adjustments checks out "headaches" in field service . . . that any flat blade reasonably accurate in width will do, thickness being a secondary consideration.

CLUTCH HEAD SCREWS

60-Second Bit Reconditioning

saves time and money . . . a brief application of the end surface to a grinding wheel sufficing to restore this Type "A" Bit to original efficiency, time and time again.

UNITED SCREW AND BOLT CORPORATION

CLEVELAND 2 CHICAGO 8 NEW YORK 7

engineer, after serving in the company's engineering department for the past eight years in various capacities.

♦

HERMAN PALTER has joined the Cleveland Hobbing Machine Co., Cleveland, as a designer. He had been a mechanical engineer with the Aircraft Engine Research Laboratory, NACA, Cleveland.

♦

WILLIAM H. RADFORD, previously associate director of research, Caterpillar Tractor Co., Peoria, Ill., has retired.

♦

FRANCIS H. CATALDO upon his discharge from the U.S. Army joined the Bobbi Motor Car Corp., San Diego, as body designer.

♦

JOHN FISHER, previously a project engineer with American Airlines Inc., has joined the Harrington Mfg. Co., Mansfield, O., as chief engineer.

♦

RUSSELL A. ENGSTROM has joined Sundstrand Machine Tool Co., Pump Division, Rockford, Ill., as experimental engineer.

♦

H. M. COOPERRIDER has become chief engineer and production manager of American Baler Co., Bellevue, O.

♦

VAUGHN HAIGH, previously a transmission engineer with Studebaker Corp., South Bend, Ind., has become affiliated with Warner Gear Division, Borg Warner Corp., Muncie, Ind., as an experimental engineer.

♦

J. P. MARTEL has been appointed manager of the design division of the engineering department, E. I. du Pont de Nemours & Co., Wilmington, Del., succeeding MELVIN F. WOOD, recently appointed assistant chief engineer of the company.

♦

C. W. BAKER, a member of the engineering staff of Lewis Foundry & Machine Division, Blaw-Knox Co., Pittsburgh, since 1929, has been appointed assistant chief engineer.

♦

HERBERT C. GRAVES JR. prior to joining Gibson Electric Co. as chief engineer had been connected with I-T-E Circuit Breaker Co. as engineering manager.

♦

FRANCIS J. LAPOINTE has been named executive vice president, Acme Broach Corp., Lexington, Ky. He has been actively engaged in broaching work for the last 44 years, and will devote his time to research and development. I. K. MCADAM will head the design department of the company.

♦

GEORGE P. EICHELSBACH JR., previously chief engineer, has been promoted to director of manufacturing and engineering, American Stove Co., Cleveland. He joined the company in 1935 as engineering draftsman, and became successively chief engineer of the St. Louis Division and chief engineer of the company.

♦

WAYNE G. NORTON has been awarded the Adolph Lomb medal by the Optical Society of America which is given to a "person under 30 years of age who shall have made a noteworthy contribution to optics". Mr. Norton is engaged in production engineering, research, design and development of fire control instruments.

♦

H. V. WILLIAMSON has been appointed director of research for Cardox Corp.

♦

DR. CLOYD HECK MARVIN has been named deputy director of the War Department's new Research and Development Division. Dr. Marvin is president of the George Washington University, and will assist in directing the division's program in the field of scientific research and development.

♦

HERBERT H. PEASE the new president of The National Machine Tool Builders' Association, is also president of the New Britain-Gridley Machine Division, The New Britain Machine Co. Born in 1881 in New Britain, Conn., Mr. Pease received his education at the New Britain high school and later at the Sheffield Scientific School of Yale University. In 1902 he joined The Stanley Works and became manager of the steel department in six years. Two years later he became associated with the New Britain Machine Co. and in 1910 was elected second vice president. In another year he was made treasurer, in 1920 president and treasurer, and in 1930 chairman of the board. He resigned as treasurer in 1936 but still remains chairman of the board and president at the present time. Mr. Pease is also a member of President Truman's Committee for Financing Foreign Trade.

♦

ROBERT H. OWENS, active in engineering and research since 1912, has recently been elected vice president in charge of engineering and manufacturing of Roots-Connersville Blower Corp. Connected with the company since 1925, he has been responsible for many new centrifugal blower and compressor developments.

♦

RALPH E. WALSH as a new member of the engineering research department of Celanese Corp. of America, Plastics Division, Newark, N. J., will design and develop machinery for the plastics division.

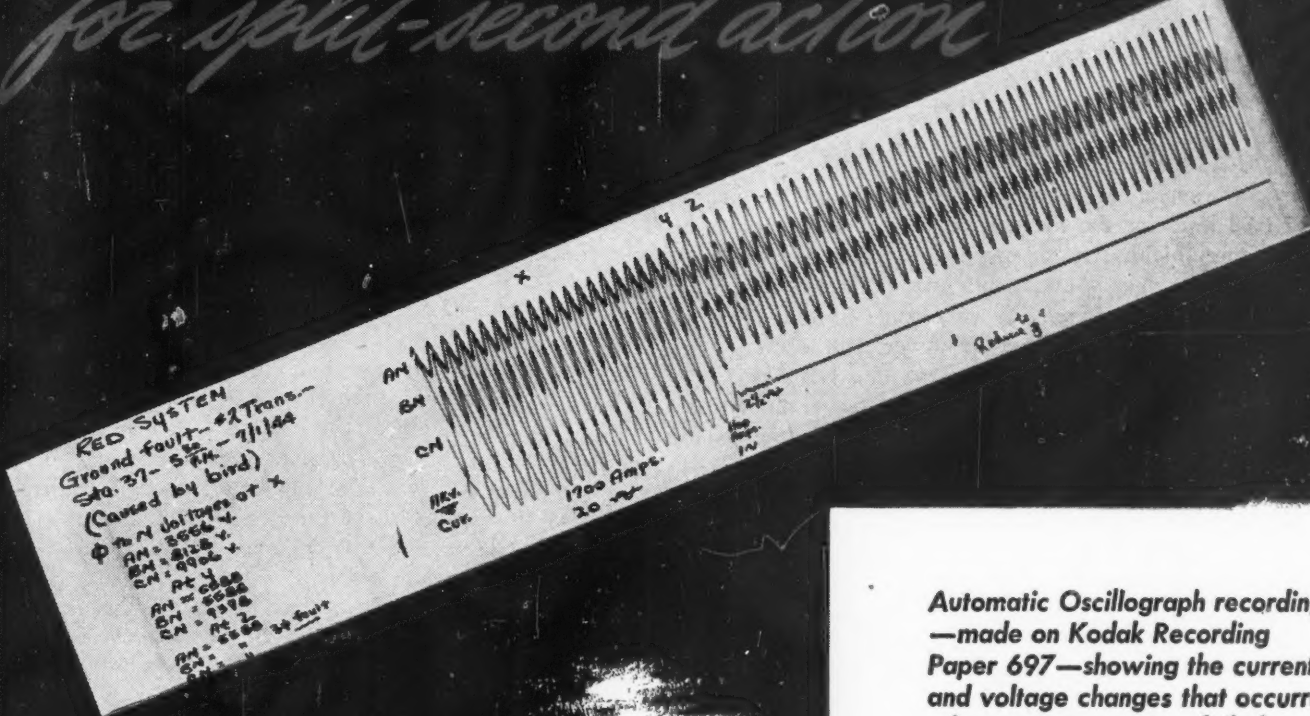
♦

J. R. GUSTAFSON has recently joined the Research and Development Division, Ford Motor Co., Dearborn, Mich. He formerly had been chief engineer with Muehlhausen Spring Corp.

♦

LEWIS W. PIFER, formerly experimental equipment engineer with Wright Aeronautical Corp., Paterson, N. J., has joined Consolidair Inc., Alliance, O., as chief engineer.

"TELL-TALE" *for split-second action*



Automatic Oscillograph recording —made on Kodak Recording Paper 697—showing the current and voltage changes that occurred when a power system failed.

Photographic-trace oscillograms tell story of unexpected trouble . . . help engineers get data on product performance

Whenever you are studying high-speed mechanical or electrical phenomena . . . whenever you need graphs of slight motions or weak currents . . . moving-mirror or cathode-ray oscillographs can help you.

They produce photographic traces that tell you the tale of split-second trouble . . . give you many kinds of information about your product and service . . .

They provide, for your study and measurement, clear, accurate photographic records . . .

And with those records made on Kodak recording papers or films, you are assured the utmost in sensitivity, quality, and uniformity in your trace reproductions.

Kodak engineers have had long experience in applying photographic materials to all phases of oscillograph recording, and offer their assistance in working out your problems.

Instrument Recording

. . . another important function of photography

EASTMAN KODAK COMPANY

Industrial Photographic Division . . . Rochester 4, N. Y.

Kodak

Design Abstracts

Improving Economy Cars

MUCH smaller than the U. S. counterpart, the average European car has a top speed of 63 mph compared with 83 mph for the average U. S. car, and employs a much more highly stressed engine. Considerations of material, fuel economy and manpower determine the size and there is little possibility of change in this respect, at least in the next decade. However, in the matter of performance the prospect of great changes has been opened up by the application of brain power in lieu of manpower. It may, indeed, be possible for the small European car to challenge the larger U. S. type in speed and durability and, at the same time, maintain or even enhance the lead held in the matter of fuel consumption.

A great deal of work has been done in Europe on the genuinely streamlined car, that is to say, an automobile with body shape determined by aerodynamic considerations rather than by style. As a result of wind tunnel tests followed by construction of full-scale prototypes, it was established that the drag could readily be halved. The consequences of such reduction are of particular importance on small cars and show that aerodynamic form is of much greater significance on the European type of car than on the U. S. type with its initially higher performance. For example, a drag reduction of 50 per cent is equivalent to a theoretical gain in maximum speed of 26 per cent. This would raise the average top speed for the European car from 63 to 80 mph with no increase in horsepower requirement, bringing it close to the average U. S. car performance. It is important that speed changes within these limits do not involve any serious embarrassment in the weight, chassis design, springing, or brake systems.

Excessive Speed Problems

This cannot be said for an aerodynamic body as applied to a larger car. Accepting 90 mph as the existing maximum speed of this type, the top speed with streamlined form would increase to 113 mph, and radical changes in all the chassis components would be required in the interests of safety, while tire problems (both wear and rapid rise in tractive loss) would become acute. Perhaps an even greater problem is the inability of the average driver to cope with maximum speeds greatly in excess of 80 mph.

From a practical point of view, the influence of reduced drag on economy—fuel consumption and length of life—is even more important than the gain in maximum speed. Improved body form therefore will make the small economy car increasingly competitive with larger types. This competition will be fortified by world developments in motor roads which will mask the inherent limitations of the small car in the aspects of hill climbing and acceleration.—*From a paper by Laurence Pomeroy, technical editor of "The Motor" (London), presented at the SAE summer meeting at French Lick, Ind.*

Bearing Test Machine Evaluated

COMPARISON of the results secured by a bearing test machine with those of actual engine tests has led to the conclusion that type of failure in the test machine is basically similar to that found in engine-tested bearings. However, following differences were noted:

1. Failures produced in bearing test machines, more than those produced in engines, progress from the point of initial break-down. The pits are apt to be considerably smaller in relation to the cracked area of bearing metal, since the accelerated test does not allow much time for the loose bearing metal to be washed or crumbled away.

2. Failure in the test machine is more likely to be confined to the 60 degrees nearest the crown of the half bearing in the rod. This is probably due to the absence of side load and to the reduced load on the cap. Occasionally some very localized fatigue is found at the edge of the relief area. This effect is believed to result from the pinching in of the rod at the parting lines when the load is directed outward on the cap. Over-heating of the contact area and local loss of fatigue resistance result.

3. Speed of failure in the test machine is, of course, much greated than in the engine; accordingly, chemical factors in the environment have less time to operate.

Except that dirt, impact and side loading are not present, the test may be regarded as a good accelerated variation on an engine test, with the understanding that these limitations prevent it from giving a final affirmative answer as to general suitability of a bearing for use. Engine and sometimes road testing are necessary for that result. The advantages of the test machine within its field of application are: Saving in working hours, with consequent low cost; earlier answers; a simpler setup with fewer moving parts to complicate interpretation of results; and the reduction of parts of unknown quality to four bearing shells.

Any simplified life test on a single part or component of an assembly is subject to criticism because of that very simplification, because part of its normal environment has been left out. However, there is merit in eliminating many of the confusing variables found in the complete assembly.

By its simpler construction, we gain a control that enables us to change many variables into constants. In the final analysis, the principal justification for this method of attack is the fact that it generally produces a rating of parts in the same order and on a similar percentage basis of quality as that found when testing in an engine. The correspondence of results in such cases is ample proof of the machine's practical value and application.—*From a paper by E. T. Johnson, Engineering Div., Chrysler Corp., Detroit, which was presented at the recent annual meeting of the ASTM in Buffalo.*

HANNIBAL'S FROZEN ASSET

The Romans smugly thought the icy barrier of the Alps impassable. But Hannibal turned the paralyzing cold to his advantage. He had water poured into the crevices of road-blocking boulders. The expansion of the freezing water "made little ones out of big ones"—and another road led to Rome.

Low temperature, which worked to Hannibal's advantage, is a distinct disadvantage to operating machinery. Under low temperature conditions, some steels that may perform perfectly at ordinary temperatures, develop unsuspected weakness. There is always danger of a parts failure under such conditions.

One way to assure good performance at low temperatures is to specify molybdenum steels. Good hardenability plus freedom from temper brittleness give them good low temperature impact strength. They are a precaution it pays not to ignore. Practical working data are available on request.

MOLYBDIC OXIDE—BRIQUETTED OR CANNED • FERROMOLYBDENUM • "CALCIUM MOLYBDATE"

CLIMAX FURNISHES AUTHORITATIVE ENGINEERING DATA ON MOLYBDENUM APPLICATIONS.

MOLY

Climax Molybdenum Company

500 Fifth Avenue • New York City

Gear-Tooth Couplings

(*Concluded from Page* 118)

the bolt circle radius; the allowable stress per bolt is based on the designer's factor of safety and the shear yield stress for the material. For the purposes of calculating torque capacity, fitted bolts give more direct answers than clearance bolts. Also, for maintaining static and dynamic balance at high speeds of the connected shafts, fitted bolts are more dependable than clearance bolts. The chief difficulty with fitted bolts is that when one flanged member is replaced, oversize reamed holes and oversize fitted bolts must be used, since a hole can be line reamed just once to any diameter. To eliminate this expense, some couplings now use bolts which are a few thousandths smaller than the bolt holes, rather than a drive fit. These bolts can be assumed to carry the torque in shear, if the holes line up.

LUBRICATION: For moderate speeds in a clean and dustless installation, with ample opportunities for inspection and repacking, a grease-packed coupling is suitable. The coupling is proportioned so that grease will flow to and lodge in the tooth area when the coupling is rotated, since the teeth are the only metallic surfaces which rub and roll on each other. The flange faces are machined with grooves and have tightly squeezed gaskets, so will not permit any grease leakage at the coupling joint. Inboard

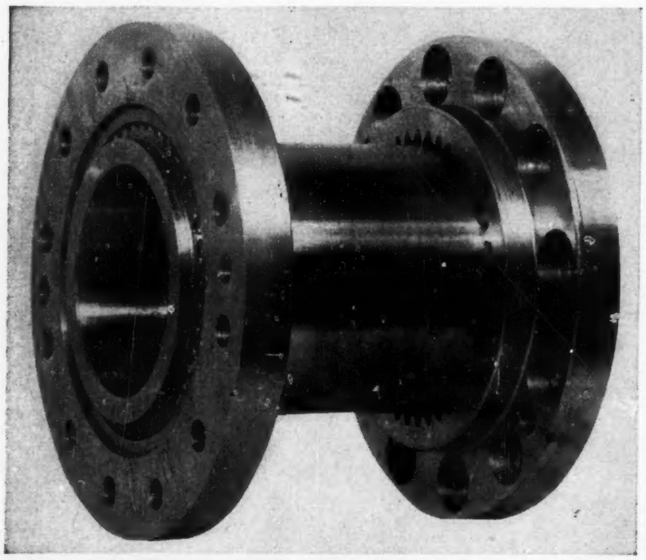


Fig. 7—Assembly of distance-piece type coupling. Flanges are attached to corresponding flanges on driving and driven shafts, using fitted bolts

ends of the sleeves are shaped in such a way as to seal in grease during operation. This coupling needs no external lubricating connections and can run entirely in the open.

A similar design uses oil-bath lubrication. The oil is poured into the sleeve until the pool reaches the hub seals, after which the filler hole is plugged and the coupling operated exactly like a greased coupling. An oil-bath lubricated coupling also does not require any special guards or nozzles, but will throw a little oil when starting or stopping if not filled properly.

Since greases tend to pack and break down when centrifuged, the limiting speed for a greased coupling should be determined by the grease manufacturer or by experience. Both the grease-packed and the oil-bath couplings should have the lubricant changed frequently, as some physical separation may take place and foreign matter often settles in the tooth spaces, causing tooth wear and reduction of flexibility.

If contamination by dust is unavoidable in the open, or peripheral speeds are high, a continuously lubricated coupling is used. Oil is fed by nozzles into a collecting lip and led to the tooth mesh by various types of passages. The oil flows through the teeth and is whirled out into an oil-tight guard with drains at the bottom. The hub-type coupling with floating sleeves has discharge holes drilled near the central part of the coupling through the sleeves. The oil-guard protects oil and coupling from contamination. In addition, the oil should be adequately filtered to remove foreign particles.

A high-speed coupling operated continuously in sooty or dust-laden surroundings will accumulate foreign particles in its extreme diameters, due to centrifugal force. This deposit may start as a barely noticeable sludge, but may turn into a hard, caked mass which eventually either reduces the oil flow to the teeth, or forms on the working surfaces of the teeth. Most coupling builders acknowledge this difficulty, in spite of many corrective steps already taken, and the operator of machinery with any kind of gear-tooth coupling should inspect and purge his coupling at regular intervals, the frequency depending upon various conditions. This problem is now receiving close attention by many builders and purchasers, and present research may solve it completely.

Which Cast Steel?

(*Concluded from Page* 105)

6. Cast steel has uniform properties in all directions and the impact strength varies as the tensile strength and response to heat treatment, this last factor being affected by the size of section and alloying composition. Quenched and tempered steels have substantially higher impact strength than annealed or normalized.
7. Designers can have perfect confidence that cast steels can be heat treated to obtain the best properties for the most economical final design. Steel castings are liquid quenched in sizes ranging from small parts, weighing a fraction of a pound, to large gears of 115-inch diameter by 24-inch face widths weighing over 15,000 pounds.
8. Physical properties of cast steels vary identically as do wrought steels. The designer therefore can utilize his previous experiences with wrought steels in directing his design activities.

A good rule to follow after preliminary designs have been made, based on the information presented, is to consult the foundry engineer and foundry metallurgist for appropriate comments which might aid in further cost reductions.

Part II of this series will present data on the commercially available cast steels, giving the properties and characteristics inherent in each which affect selection for machine elements.

Good Sales Point for Portable Tools

—A CORD JACKETED WITH

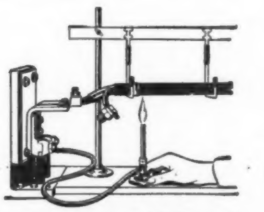
TOUGH, DURABLE
NEOPRENE

RESISTS WEAR

Gives a tough, flexible armor to the cord. Resists wear and abrasion, cutting and chipping.

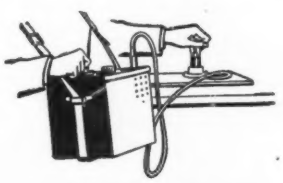
RESISTS SUNLIGHT

10-year exposure tests have proved neoprene jackets stand up under sunlight and weathering.



FLAME RETARDING

Neoprene jackets can be compounded to meet new Pennsylvania requirements for flame resistance in mine cable.



RESISTS OZONE

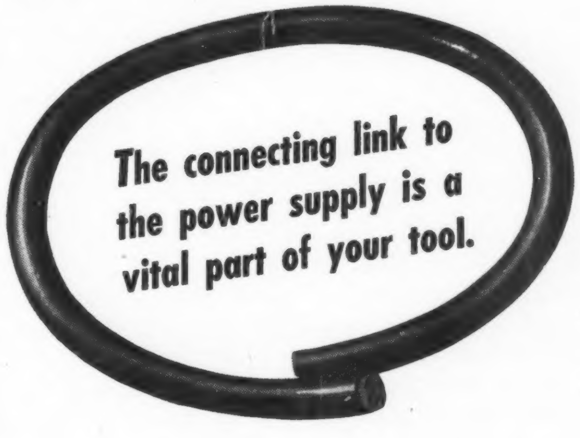
Protects insulation against deterioration from ozone, oxygen and air.

RESISTS OIL

Stands up under contact with oil and gasoline. Resists most solvents, chemicals and acids.

RESISTS HEAT

Does not soften at elevated temperatures. Successfully used at 180-250°F.



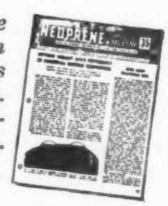
NOW that the "sellers' market" is showing signs of slackening, you can plan ahead for competitive selling by making sure the cords on your portable tools are jacketed with neoprene. Your Sales Department will realize the added prestige accorded your product because of this plus value—when repeat orders come in.

You'll be on sound engineering ground, too—for a good tool deserves a good cord, and you get the best when you specify a neoprene-jacketed cord.

Here's Why Neoprene DOES SO MANY JOBS SO WELL!

- ★ High tensile strength, resilience, low permanent distortion.
- ★ Tough and durable, resists abrasion and cutting.
- ★ Superior resistance to sunlight, aging, ozone, and heat.
- ★ Resistance to deterioration by oils, solvents, chemicals, acids.
- ★ Superior air-retention, low permeability to gases and fluids.
- ★ Special compositions are flame-retarding, static-conducting, flexible at low temperatures.

***Write for** your free subscription to The Neoprene Notebook. Packed with information about new or unusual neoprene applications —which may give you valuable new ideas. Back issues on request. Rubber Chemicals Division A-12, E. I. du Pont de Nemours & Co. (Inc.), Wilmington 98, Delaware.*



Design for Success with

DU PONT NEOPRENE

The VERSATILE Synthetic Rubber

BETTER THINGS FOR BETTER LIVING
... THROUGH CHEMISTRY

DU PONT
REG. U. S. PAT. OFF.

Mechanical Seals

(*Concluded from Page* 150)

It can be seen at a glance that the ratio of power to face load is constant here, too. At 150 pounds, for example, the absorption is about one-half horsepower where $f = 0.100$. At 300 pounds it is about one horsepower. *Fig.* 36 is a similar set of curves except that a friction coefficient of 0.100 is assumed, and curves are shown for face widths of ⅛, ¼, and ⅜-inch. The ratio of power to face load is still constant, of course, but of considerable interest is the fact that changes in face width have little effect in displacing the curve.

Face Width

The reason for this is apparent when one recalls that the inside and outside diameters of the contact area enter into the calculation by the quantity $(D^3-d^3)/(D^2-d^2)$, changes in which are relatively small for changes in $(D-d)/2$. This is readily seen in *Fig.* 37, which shows how horsepower varies with changes in face width from 1/16 to 3/8-in. for shaft diameters of 1, 2, and 3 in., the assumptions being a speed of 1800 rpm, a friction coefficient of 0.100, and a face load of 200 pounds. *Fig.* 38 illustrates the same point, except that a shaft of 2-in. diameter is assumed, and curves are shown for friction coefficients of 0.050, 0.100, and 0.150. The middle curve of each graph, for example, indicates that if the face width is multiplied by six, increasing it from 1/16 to 3/8-in., the power absorption is increased only 11 per cent, from 0.63 to 0.70.

If this be true there naturally arises the question of how wide the faces should be, since face width has so little effect on power consumption. This again brings up elements which are not fully understood. Is there a pressure gradient across a seal face, or is the condition analogous to an ordinary gasket? To put it differently, if pressure readings were taken along a radial line across a pair of 3/8-in. sealing faces with a pressure of 150 psi imposed at one edge, would the pressure be 100 psi 1/8-in. from that edge, 50 psi 1/4 from it, and zero at the opposite edge? If not, would the pressure drop off more rapidly in the first 1/8-in, say, than in the last 1/8-in.? Would it drop off less rapidly? Or, applying gasket theory, would it be zero almost immediately, the remainder of the face "backing up" the edge nearest the pressure? Until answers to these questions are available the seal designer should select a face from about 1/8-in. to about 3/8-in., a range shown by usage to be adequate for most purposes.

One further point, not dealing strictly with face width, should be mentioned because it might easily be misunderstood. It might be thought that, since face width has such little effect on absorbed power, shaft diameter is not very important. That is not true. The basic quantity for face width calculation is not D and it is not d. It is $D-d$, and the quantity $(D^3-d^3)/(D^2-d^2)$ derived from the same source is nearly constant for a given d as long as $(D-d)/2$ does not exceed about 0.375, which is the maximum in ordinary sealing. But the magnitude of the near constant varies almost directly with d, and it is this property that should be kept in mind. The shaft diameter, it follows, should be kept to the minimum wherever possible.

This is illustrated in *Fig.* 39, showing how power absorption varies with shaft diameter for speeds of 3600, 1800, and 900 rpm, a friction coefficient of 0.100, a face load of 200 pounds, and a face width of 1/4-in. being assumed. Under these conditions it can be seen that a seal on a 1-in. shaft turning 3600 rpm will absorb about 0.75 horsepower, and if the shaft diameter is doubled to 2 in. the power absorption becomes almost double, actually 1.33. *Fig.* 40 illustrates the same point, except that a speed of 1800 rpm is assumed and curves are shown for face loads of 300, 200, and 50 pounds.

Co-operation in Design Is Essential

Keeping the shaft diameter to the minimum entails a certain amount of correlation between departments. The reasons for close co-operation between a seal manufacturer and the manufacturer of equipment in which seals are to be used apply with equal force to the situation where the equipment manufacturer has decided to make his own seals. There should be a close co-operation between the department responsible for the machine design and the department responsible for the seal design. In companies of moderate size the machine and seal designers, if not the same man, are probably drawing room neighbors, and co-operation usually follows as a matter of course. But in large companies making many different kinds of equipment it might well be preferred to give the seal designing job to a division whose function is the development of new items or procedures in general. In such cases the seal project should not be removed too far from the designers of the machine itself. Revision of elements in the machine for best seal performance and development of the seal itself are so closely related that only good teamwork can produce the desired results. Company politics or red tape should never be permitted to interfere. The task is not always easy, and it may require much genius and more patience, but there are few rotating shafts to which mechanical seals cannot be applied if the designers work together intelligently and with reasonable freedom.

Lightweight Bodies Show Economies

COMMERCIAL motor vehicles using bodies of aluminum, magnesium and stainless steel have demonstrated experimentally that these materials can contribute substantially to speed, economy and convenience of highway transportation. J. H. Dunn of Aluminum Co. of America reported at a recent SAE National Transportation and Maintenance meeting that aluminum bodies for trucks assure advantages on the order of 10 per cent less fuel consumption, 25 per cent greater tire mileage expectancy and 10 per cent step-up in acceleration. Magnesium was characterized as eminently suitable for truck bodies with comparable savings. Lightweight bodies also tend to localize unavoidable damage and actually protect engine and chassis by absorbing shocks.

For

Better, Faster Service

On Your

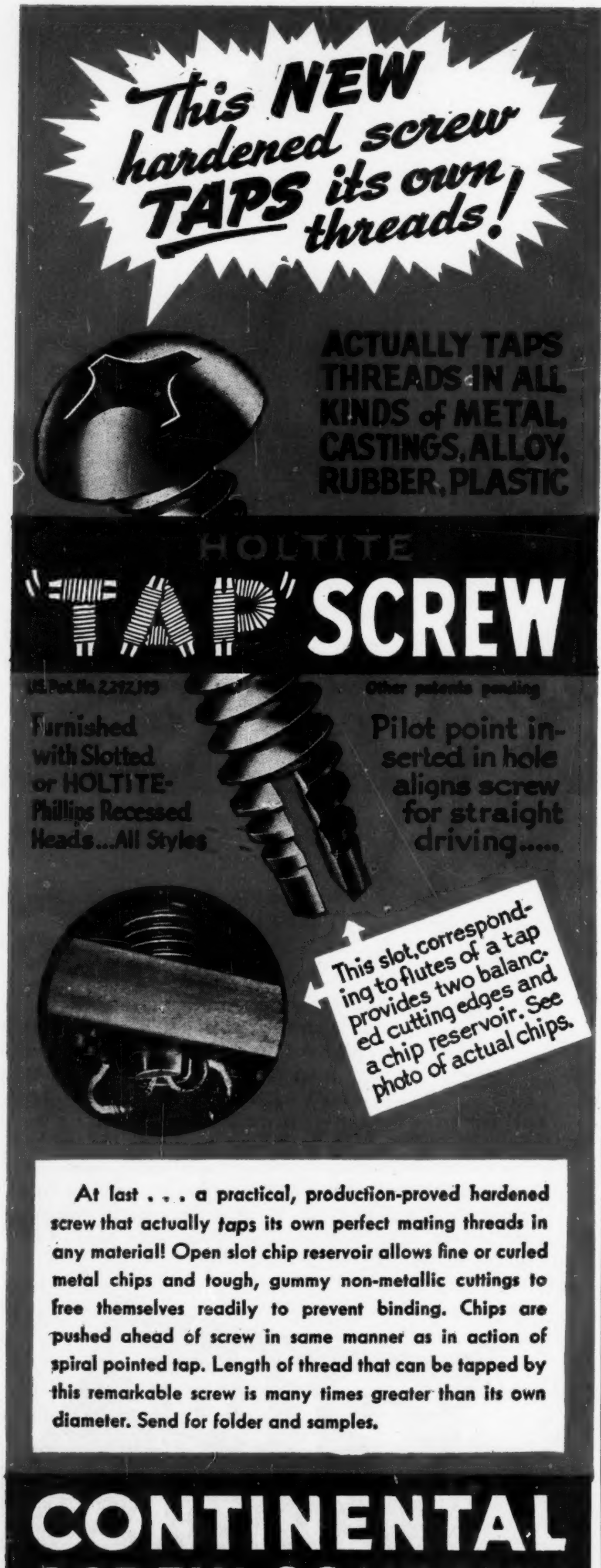
FRACTIONAL H.P. MOTOR PROBLEMS

. . . Use Our Direct Factory Representation by Trained Fractional H. P. Engineers

Through our engineers, we make available to you an accumulated wealth of F.H.P. motor engineering and production know-how. Consult with us NOW if your plans call for production-run quantities of small motors (1/500 to 1/15 H.P.) or blowers. A skilled, experienced factory engineer will help you solve your engineering and production problems right in your own plant . . . may help you lower product costs, improve product performance. Write today, outlining your problem.

F. A. SMITH MANUFACTURING CO., INC.
550 DAVIS STREET ROCHESTER 2, N. Y.
FASCO

Pilot
Fractional H.P.
MOTORS
& BLOWERS



BUSINESS AND SALES BRIEFS

APPOINTMENT of James E. Stevenson as manager of V-belt sales has been announced by United States Rubber Co. During the past seven years he served as New York district sales manager of the L. H. Gilmer Co., a division of United States Rubber.

◆

Formerly sales engineer for S K F Industries, Kenneth F. Thomas has been named district engineer for the New England office of The Kaydon Engineering Corp. of Muskegon, Mich., manufacturer of all types of ball and roller bearings. His offices are at 62 La Salle Road, West Hartford, Conn.

◆

A new organization specializing in industrial design has been formed by Geo. W. Hayman at 37 N. Village Ave., Rockville Centre, N. Y. The company is made up entirely of veterans, all experienced engineers and designers.

◆

Opening of a new office at 332 South Michigan Ave., Chicago, has been announced by the Fittings Division of Ladish Drop Forge Co., Cudahy, Wis. W. O. Kupper will head the new office as manager of middle western sales. He will direct the sale of the complete line of Ladish seamless welding fittings, forged steel fittings and forged steel flanges. Formerly Mr. Kupper was manager of southern sales for the Fittings Division.

◆

Ahlberg Bearing Co. of Chicago has appointed P. J. Aquilino and Henry J. Shuster as assistant managers of the Washington and Philadelphia branches, respectively. Both men will be under the direction of James Herman, who recently was made Eastern district manager.

◆

Henceforth Spicer Mfg. Corp. will be known as the Spicer Mfg. Division of the Dana Corp. No other change in any phase of the organization has resulted.

◆

Removal of its offices and plant from 1030 North McCadden Place, Hollywood, to 11916 West Pico Blvd., Los Angeles 34, has been announced by Lear Inc. of California. The new location provides increased space and improved facilities for sales, service and development work.

◆

Walter B. Briggs has been named general manager of the Power Transmission Division of Lovejoy Flexible Coupling Co., Chicago. Formerly he was manager of the Power Transmission Division of Ideal Industries Inc.

◆

As a result of rapidly increasing industrial activity in the Southwest, Cutler-Hammer Inc. has raised the status of the branch sales office at Dallas, Tex., to that of a district office, with E. K. Anderson in charge as district manager. The office is located at 715-A North Ervay St. and covers the states of Texas, Oklahoma, Arkansas and southern New Mexico. J. S. Darby, in charge of the branch sales office in Houston, will

You can't blame the ladies
for loving Stainless!

THE weaker sex has developed a strong attachment for this aristocrat of steels. And no wonder. Its beauty, its cleanliness, its long-life service are so outstanding that Stainless Steel has endeared itself to feminine hearts.

So, if your product is intended for the housewife and can be made of wire, make it of Stainless Steel and you give it added value and irresistible sales appeal.

In egg beaters, cream whippers, potato mashers, pot and pan handles, wire trays, drying racks and refrigerator shelves, and countless other household gadgets, U·S·S Stainless Steel Wire adds but little to the cost—but will add immeasurably to selling power.

And this is important — U·S·S Stainless Steel Wire for such applications is available NOW—for *immediate* delivery — in any quantity desired.

Our wire specialists will gladly help you in applying this perfected, service-tested Stainless Wire to your product—to insure greatest economy in manufacture and utmost satisfaction in service. Write us.

If you make it of WIRE...make it of the BEST!

USS AMERICAN MANUFACTURERS WIRE UNITED STATES STEEL

American Steel & Wire Company
Cleveland · Chicago · New York
Columbia Steel Company
San Francisco · Los Angeles · Portland · Seattle · Salt Lake City
Tennessee Coal, Iron & Railroad Company, Birmingham, *Southern Distributors*
United States Steel Export Company, New York

UNITED STATES STEEL

operate under the supervision of the Dallas district. Also announced by the company is the appointment of Joseph P. Simon as district manager of the Philadelphia territory to succeed the late D. J. Quammen. Mr. Simon will have direct charge of all sales in the Philadelphia territory and will supervise the branch offices at Baltimore, Washington, D. C., and York, Pa.

♦

Opening of a new Cleveland office at 3091 Mayfield Road has been announced by Landis Tool Co. of Waynesboro, Pa. P. E. Beaver, previously with the Chicago office, has been placed in charge as manager.

♦

With headquarters at 601 East Robinson St., Pittsburgh, Frank P. Smith has been appointed sales engineer in the Cleveland region for E. I. du Pont de Nemours & Co. He will report to W. E. Kreuer, regional industrial sales manager in Cleveland.

♦

Construction of a new plant in Niles, O., for the manufacture of railroad journal bearings is underway by the American Brake Shoe Co. When completed, the plant will be operated by the National Bearing Division.

♦

Previously sales manager, Norbert C. Rubin has been named vice president in charge of sales for the Yoder Co., Cleveland. He will work in close collaboration with John I. Lucas, president of the company. Also announced is the appointment of William J. Kerr as vice president in charge of production. Formerly he had been factory manager.

♦

After three years in the Navy as a welding engineer, R. W. Sharp has returned to The Lincoln Electric Co., Cleveland, and will serve as district manager and sales engineer of the newly established Indianapolis office at 3343 Central Ave. Before he joined the Navy he covered the Kentucky and southern Indiana territory of the company.

♦

Handy & Harman, New York, is constructing a new plant at 3625 Medford St., Los Angeles, to meet the increased demand for gold and silver as well as refining service on the Pacific coast. The Los Angeles office of the company will be moved to this new location when the plant is completed.

♦

Removal of all facilities to its own building at Califon, N. J., has been announced by St. John X-Ray Laboratory.

♦

Fred C. Ziesenheim has been appointed sales manager of the Plastics & Die Casting Machinery Divisions of The Hydraulic Press Mfg. Co., Mount Gilead, O. He will direct the sales and assist in the development of new machines for these two divisions.

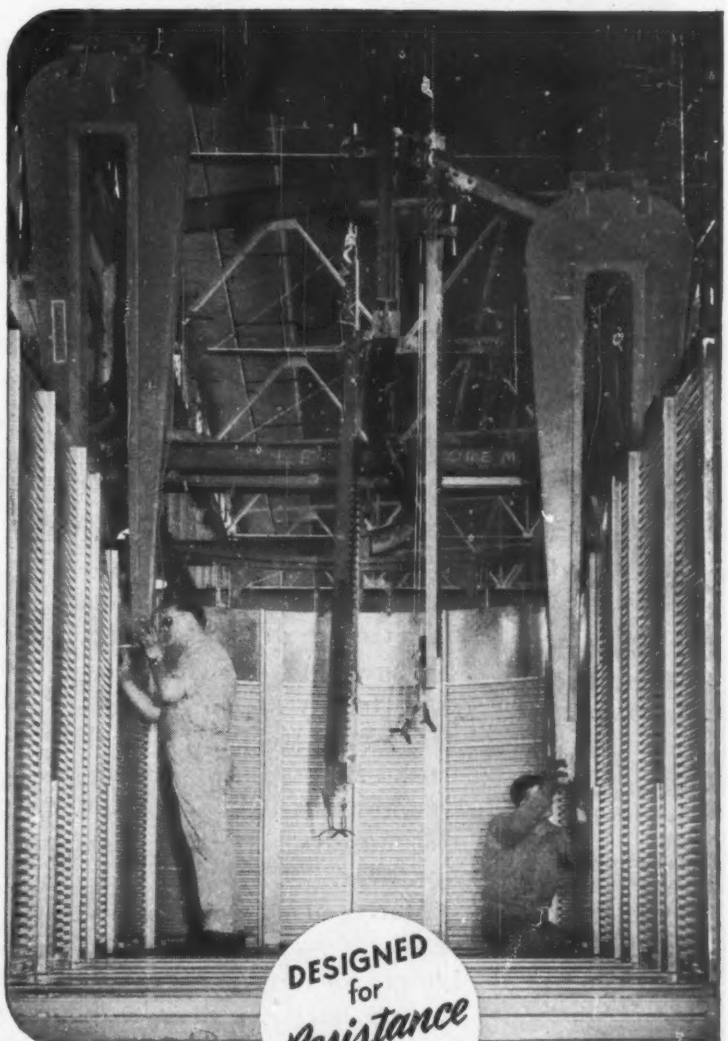
♦

According to a recent announcement by Northern Industrial Chemical Co., the New York area sales office has been moved from 1180 Raymond Blvd., Newark, N. J., to 441 Lexington Ave., New York. F. C. Meacham serves as manager in charge of the metropolitan area.

♦

With headquarters at the Chicago office at 311 South Green St., Clyde B. Colwell has been named special representative for stainless steels by the Jessop Steel Co. of Washington, Pa. He

There really wasn't any other way to design them—

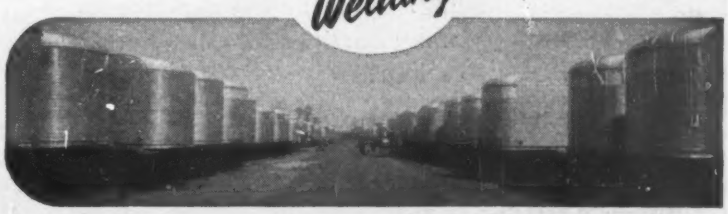


WHEN Fruehauf designed its now famous stainless steel truck-trailer it went after real mass production: not just a couple of hand assembled trailers a day—but a complete trailer off the line every 45 minutes.

There were two ways to do a job like that. Either Fruehauf could build enormous plants with many assembly lines and use relatively slow equipment—or it could design the trailers for assembling by resistance welding from stem to stern, from roof to undercarriage.

Since the latter enabled Fruehauf to turn out highest quality trailers faster and at lower cost, there wasn't any real question in the end. Every one of these Fruehaufs rolling off the line is doing so through benefit of Progressive welding guns—push guns, scissors guns, C-type guns, little guns and big ones like those shown here.

Progressive's engineers will be glad to help you design your products so that they can be built better, faster and at lower cost with resistance welding.



IT PAYS TO WELD

MEMBER RESISTANCE WELDER MANUFACTURERS ASSOCIATION RWMA

PROGRESSIVE *Welder Co.* 3050 E. OUTER DRIVE • DETROIT 12

RESISTANCE WELDING EQUIPMENT

It's Adaptable to Many Uses Like These:

- Excluding dirt, grit, dust, etc.
- Retaining lubricants
- Thermostatic insulation
- Isolating vibration
- Cushioning shock
- Electrical insulation
- Weight reduction
- Temperature control
- Padding, packing, seals
- Air and liquid filters
- Gaskets, channels, etc.
- Grinding, polishing, etc.
- Instrument mounts

Acadia Synthetic Division, Processors of Synthetic Rubber and Plastics: Sheets, Extrusions and Molded Parts.

Machine designers find many advantages in cut felt parts—for improved performance and functional dependability. Western Felt is readily processed to any specific consistency—from wool soft to rock hard. It's resilient, flexible, compressible, etc.—with high resistance to oil, water, heat, age, wear.

Machined or turned, ground or punched—Western Felt finishes to micrometer tolerances . . . and holds its shape perfectly without fraying or ravelling. You'll find it superior in many qualities for parts applications.

Tell us the characteristics you want. Our engineers are ready to help you answer any problems that concern the possible uses of felt.

WESTERN FELT WORKS
4035-4117 Ogden Avenue, Chicago 23, Illinois
Branches in all Principal Cities
LARGEST INDEPENDENT MANUFACTURERS AND CUTTERS OF WOOL, HAIR, AND JUTE FELTS

will specialize in the sale of solid stainless steels, stainless-clad steels, stainless steel castings, heat resisting castings and acid resisting castings. Formerly he was employed in the sales department of the Carnegie-Illinois Steel Corp. where he was engaged mainly in the sale of alloy and stainless steels.

♦

Celanese Corp. of America has appointed Frank Sanford to succeed J. J. Keville Jr. as assistant director of sales of the molding materials department of the Plastics Division. Headed by W. R. Porter, this department is responsible for the sales of Lumarith, Celcon and Forticel to molders.

♦

A national sales office has been opened at 549 West Washington Blvd., Chicago, by the Montgomery Mfg. Co., formerly known as Montgomery Time Systems. Ralph T. Brengle has been placed in charge of the new office.

♦

Borg-Warner Corp. has purchased from the War Assets Administration the manufacturing plant in Milwaukee County, Wis., which was operated during the war by the A. O. Smith Corp. for the production of airplane propellers. The newly purchased plant is intended for use by the corporation's newly formed Wisconsin Transmission Division and will not be fully equipped or ready for operation until the latter half of 1947.

♦

Appointment of E. C. Coombs as assistant sales manager has been announced by The Federal Machine & Welder Co., Warren, O. Formerly he was chief service engineer and assistant manager of sales engineering.

♦

To succeed C. R. Churchill who died recently, the Standard Transformer Co. of Warren, O., has appointed the Southwest Sales & Service Co. of Shreveport, La., to serve as its representative in the states of Louisiana, Mississippi and Arkansas.

♦

Opening of a new Cincinnati office at 426-428 Elm St. has been announced by Independent Tool Co., Chicago. W. C. Rush, formerly in the St. Louis office, has been placed in charge as manager. Also announced by the company is the appointment of J. A. Hill as manager of electric tool sales, with headquarters at the company's general offices in Chicago. Mr. Hill previously served as manager of the New York branch office.

♦

Allen McKee Bond Jr. has been named sales manager of the fats and oils section of the Votator Division, the Girdler Corp., Louisville. He joined Votator's technical staff in January and has had an important part in the company's comprehensive research projects and enlarged engineering service program.

♦

To serve as its regional representative in the central states, The Lindsay Corp. has appointed Reinhofer & Breaux, 222 West Adams St., Chicago 6.

♦

Following the resignation of A. E. Caudle, Allis-Chalmers Mfg. Co. of Milwaukee has promoted Charles F. Codrington from assistant to the manager to sales manager of the blower and compressor department. Ned Landis has been appointed branch manager of the Syracuse, N. Y., office to succeed Leonard R. Reid who is now attached to the electrical department at the company's main works. Albert R. Knauss, formerly

ess-clad
d acid
les de-
vas en-

anford
ales of
vision.
ble for

Wash-
rmerly
le has

Assets
ounty,
Smith
newly
newly
fully
1947.

nager
Co.,
d as-

dard
hwest
epre-
nsas.

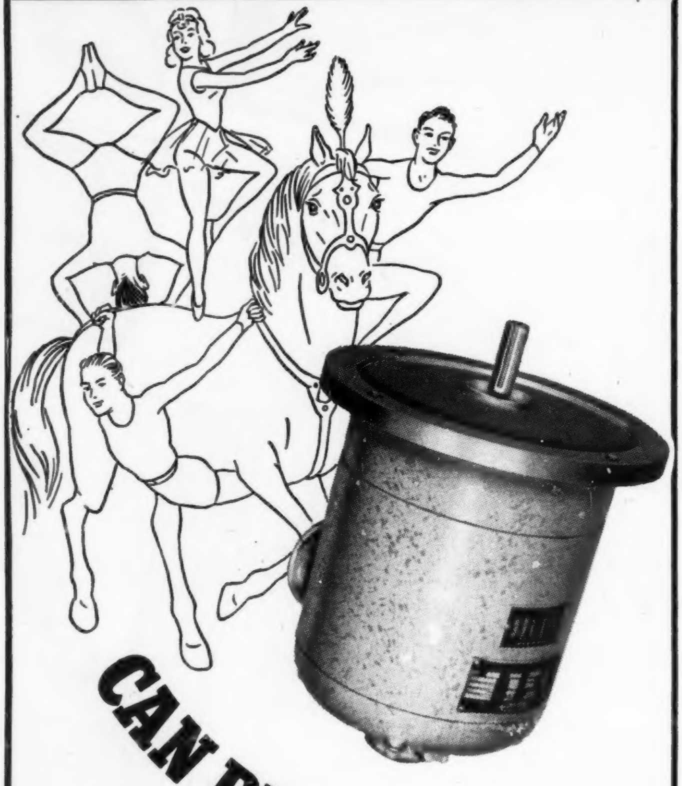
St.
V. C.
d in
the
ales,
Chi-
New

the
orp.,
and
re-

tes,
222

ners
ton
wer
ted
eed
art-
rly

946



CAN BE MOUNTED IN ANY POSITION

A simple flange mounting of a Welco Torque Motor puts the drive of a machine on the spot where it's needed. Because an instant flow of power is certain, even when standing on its head, a Welco Motor can be fitted in close quarters instead of using a remote drive system of pulleys and belts. Just four bolts put a Welco Torque Motor in perfect alignment for quick starts and stops, holding, clamping, indexing and reversing. A.C. or D.C. interchangeable mounting dimensions.

Construction and maintenance costs are cut and appearance of machine is improved.

Welco Motors are not for standard applications. They are specially designed to your specifications for out-of-the-ordinary powering problems.

THE B. A. WESCHE ELECTRIC CO.
1622-12 VINE ST. CINCINNATI 10, OHIO

with the Tulsa district office, has been named manager of the office at Memphis, Tenn.

♦

Recently announced is the appointment of Robert C. Neiswander as sales manager of The Hertner Electric Co., Cleveland, manufacturer of motor-generator battery-chargers for industrial lift-trucks, motor-generators for the telephone industry, and Transverters for motion-picture theaters. The company expects to build a complete line of NEMA integral polyphase motors.

Meetings and Expositions

Jan. 6-10—

Society of Automotive Engineers Inc. Annual meeting and engineering display to be held at Book-Cadillac Hotel, Detroit. John A. C. Warner, 29 West 39th St., New York 18, is secretary and general manager.

Jan. 14-17—

National Materials Handling Exposition to be held at Public Auditorium, Cleveland. Additional information may be obtained from Clapp & Poliak Inc., 37 Wall St., New York.

Jan. 23-26—

Society of the Plastics Industry. Second conference and exhibit of the Low-Pressure Division to be held at Edgewater Beach Hotel, Chicago. W. T. Cruse, 295 Madison Ave., New York, is executive vice president of the society.

Jan. 27-31—

American Society of Heating and Ventilating Engineers. Fifty-third annual meeting to be held in conjunction with seventh international heating and ventilating exposition at Lakeside Hall, Cleveland. Charles F. Roth, Grand Central Palace, New York, is manager of the exposition.

Jan. 28-29—

National Warm Air Heating & Air Conditioning Association. Thirty-third annual meeting to be held at Hotel Cleveland, Cleveland. George Boeddener, 145 Public Square, Cleveland 14, is managing director.

Feb. 24-28—

American Society for Testing Materials. Spring meeting to be held at Benjamin Franklin Hotel, Philadelphia. Technical feature of the meeting will be a symposium on testing and evaluation of paints and paint materials. R. J. Painter, 1916 Race St., Philadelphia 3, is assistant to the secretary.

March 22-27—

Fifth Western Metal Congress and Exposition, sponsored by American Society for Metals, to be held in the San Francisco-Oakland Golden Gate area. Technical meetings and industrial exhibits will be at the Oakland Civic Auditoriums. W. H. Eisenman, 7301 Euclid Ave., Cleveland 3, is secretary of the society and managing director of the congress and exposition.

March 31-April 2—

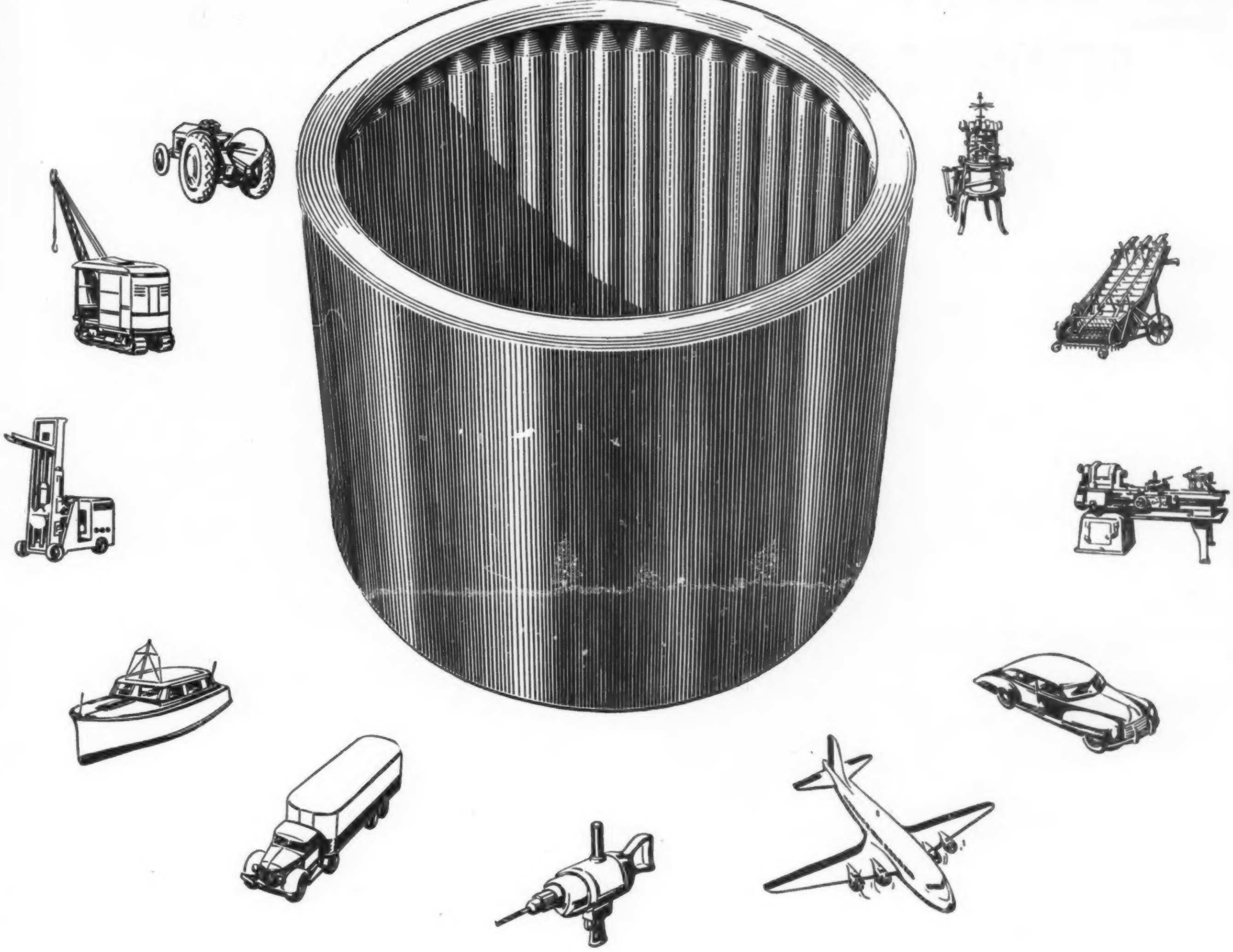
Midwest Power Conference, sponsored by Illinois Institute of Technology, to be held at Palmer House, Chicago. Professor Stanton E. Winston, Illinois Institute, is conference director.

April 7-10—

National Association of Corrosion Engineers. Annual convention to be held at Palmer House, Chicago. Elton Sterrett, 905 Southern Standard Bldg., Houston 2, Tex., is executive secretary.

April 9-11—

Society of Automotive Engineers Inc. National aeronautic meeting (spring) to be held at Hotel New Yorker, New York. John A. C. Warner, 29 West 39th St., New York 18, is secretary and general manager.



It has an ever widening circle of application

In virtually every type of mechanical equipment, Torrington Needle Bearings are serving in an increasingly varied range of applications . . . whatever the load and speed requirements.

The reason lies both in their tremendous radial capacity—greater in relation to O.D. than in any comparable bearing—and in their low coefficient of starting and running friction —with no practical speed limitation on their application. Behind these advantages lies the principle of Needle Bearing design—a full complement of small diameter precision rollers which provide maximum area of bearing contact surface.

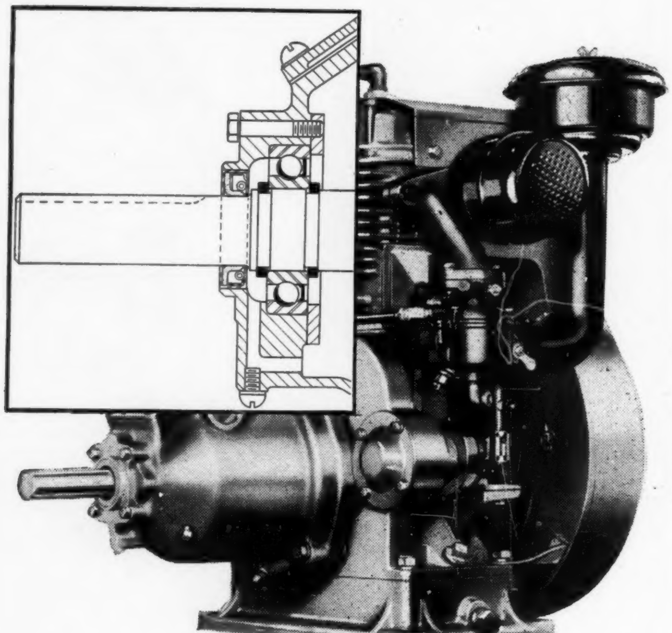
Then too, many other important Needle Bearing features — compact size, unit construction for easy installation, efficiency of lubrication and low initial cost—widen the scope of their application to modern machines.

As a designer, manufacturer or operator of mechanical equipment, you should know about these and other Torrington Needle Bearing advantages. Write today for our Catalog #32, or consult our Engineering Staff on any specific friction problem.

THE TORRINGTON COMPANY
TORRINGTON, CONN. SOUTH BEND 21, IND.
Offices in All Principal Cities

TORRINGTON NEEDLE BEARINGS

SAVE WHEREVER YOU CAN RETAINING RINGS WILL HELP!!!



These inexpensive, efficient artificial shoulders save metal and money on these Wisconsin air cooled heavy duty engines.

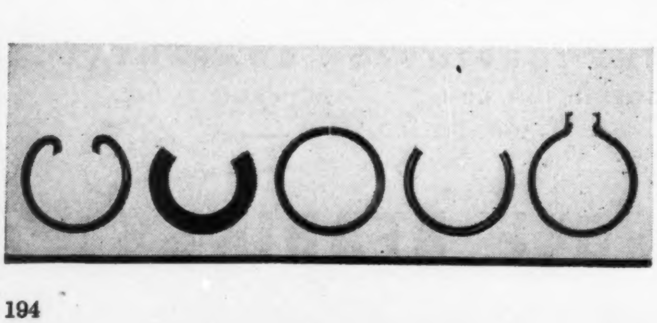
Every product—metal, wooden or plastic—and every machine should be examined now to see where shoulders and collars can be redesigned to effect great savings by the use of steel retaining rings.

Let us show you how they can do an efficient job for you.

Write today for booklets on many types of National Retaining Rings.

THE NATIONAL LOCK WASHER COMPANY

NEWARK 5, N. J. MILWAUKEE 2, WISCONSIN



New Machines

And the Companies Behind Them

Aircraft

Three-runner, pusher-type, snow plane, Price Snoplane Co., Durango, Colo.

Automotive

3-15-ton capacity trucks, Four Wheel Drive Auto Co., Clintonville, Wis.
Motor-generator charger for truck batteries, The Hertner Electric Co., Cleveland.

Baking

Parkerhouse roll machine, Quick-Seal Inc., Kansas City 6, Mo.

Ceramics

De-airing combination machine, Chambers Bros. Co., Philadelphia.
Stoker, U. S. Machine Corp., Lebanon, Ind.
De-ironers, Dings Magnetic Separator Co., Milwaukee 7.
Two-dip immersion vapor degreaser, Detrex Corp., Detroit.
Floor sweeper, The Moto Mower Co., Detroit.
Small electric kiln or furnace, Pereny Equipment Co., Columbus, O.

Chemical

Rotary drier, L. R. Christie Co., New York.

Construction

Concrete mixer, Kwik-Mix Co., Port Washington, Wis.

Diesel

Air-cooled 3¾ hp diesel engine, R. H. Sheppard Co. Inc., Hanover, Pa.

Domestic

Electric dishwasher, Hurley Machine Div., Electric Household Utilities Corp., Chicago.
Gas conversion burner, L. J. Mueller Furnace Co., Milwaukee 7.
Oil burning home heater, Evans Products Co., Detroit 27.
12 and 16-inch kitchen ventilating fans, The Emerson Electric Mfg. Co., St. Louis.
Mantle clock, General Electric Co., Bridgeport 2, Conn.
Travel iron, General Electric Co., Bridgeport 2, Conn.
Electric fans, Westinghouse Electric Corp., Pittsburgh 30.
Thin-wall kitchen fans, Ilg Electric Ventilating Co., Chicago.

Food

Fruit and vegetable bagger, Food Machinery Corp., Dunedin, Fla.
Automatic frankfurter banding machine, Marathon Corp., Menasha, Wis.
Mustard mill, The Jayhawk Mfg. Co., Hutchison, Kans.
Automatic machine to remove rancidity, excess acids, etc., from oils, Honan-Crane Corp., Lebanon, Ind.

Heat Treating

High-speed steel hardening furnace, The Sentry Co., Foxboro, Mass.
Pusher-tray furnace, W. S. Rockwell Co., Fairfield, Conn.
Top-fired crucible melting furnace, Radiant Combustion Inc., Warren, O.
Muffle-type electric furnace, Cooley Electric Mfg. Corp., Indianapolis.
High-temperature furnace, K. H. Huppert Co., Chicago 37.
Gas cracking unit, Bellevue Industrial Furnace Co., Detroit 7.
High-frequency induction heater, Induction Heating Corp., New York 3.

Industrial

Degreaser for metal cleaning, Vapor Engineering Corp., Los Angeles 13.
Liquid honing unit, Vapor Blast Mfg. Co., Milwaukee.
Spinner-riveter, The Plymouth Engineering Co., Plymouth, Ind.
Portable dial scale, Howe Scale Co., Rutland, Vt.
Portable fire extinguishing unit, Cardox Corp., Chicago.
Shakeout with automatic flask loader, Robins Conveyors Inc., Passaic, N. J.
Flexible shaft utility tool, The Dumore Co., Racine, Wis.

Laboratory

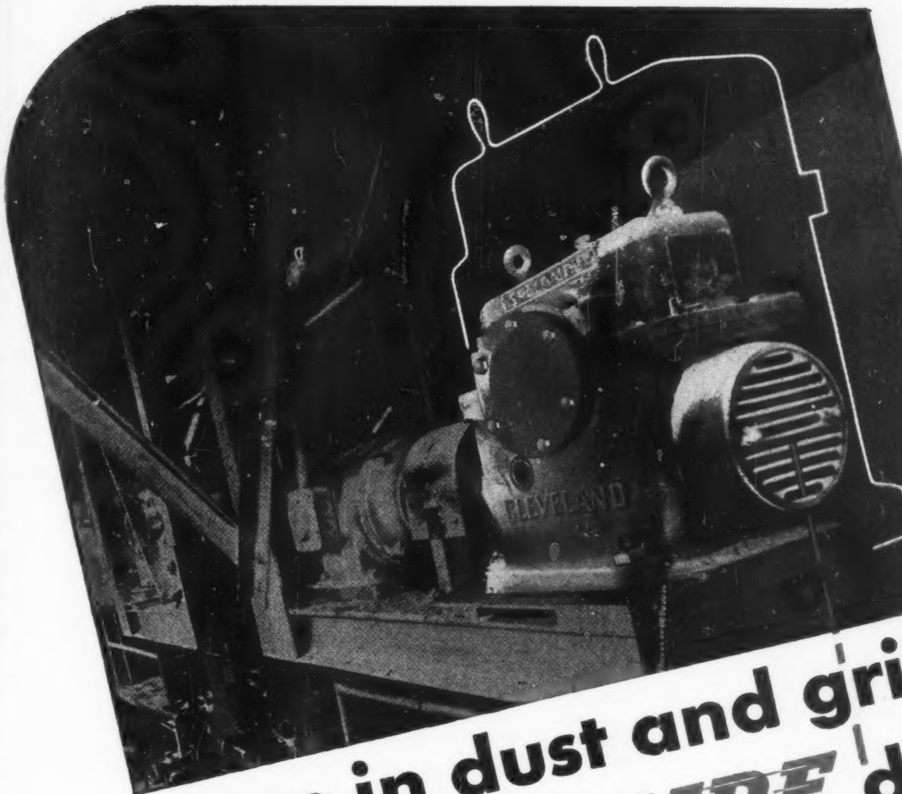
Supersonic generator, Fisher Scientific Co., Pittsburgh.

Lubrication

Center island lubrication unit, Aro Equipment Corp., Bryan, O.

Materials Handling

Electric lift truck, Yale & Towne Mfg. Co., Philadelphia 24.
Load lifter, Service Caster & Truck Div., Domestic Industries Inc., Albion, Mich.
All-steel conveyor, Galvin Mfg. Corp., Chicago.
Lightweight roller-type gravity conveyor, The Dow Chemical Co., Midland, Mich.
Hydraulic high-lift truck, Lyon Raymond Corp., Greene, N. Y.
Portable stamping conveyor, Rapids-Standard Co. Inc., Grand Rapids 2, Mich.
Hand trucks, Arrow Products, Grand Rapids 4, Mich.
Ten-ton truck, Elwell Parker Electric Co., Cleveand.
Mobile loader, Athey Products Corp., Chicago.
Side-mounted motor lift-truck, Towmotor Corp., Cleveland 10.
Electrically propelled hand truck, Automatic Transportation Co., Chicago 20.
All-electric lift-truck, Barrett-Cravens Co., Chicago 23.
50-ton hydraulic speed jacks, The Buda Co., Harvey, Ill.
4000-lb capacity electric power fork truck, Lewis-Shepard Products Inc., Watertown 72, Mass.
Electric hoist line with 2-ton unit, The Yale & Towne Mfg. Co., Philadelphia 24.



As the white outline indicates, a standard unit of nearly twice the frame size would be required to do the work of Speedaire.

Even in dust and grime SPEEDAIRE does the job

DRIVING doctor rolls on starch dehydrating machines in a Chicago plant, the Speedaires shown above give their owner these three benefits:

1. **A money saving of $39 on each Speedaire drive, compared to conventional worm-gear reducers.**
2. **With space at a premium, compact Speedaire proved ideal for this application.**
3. **In spite of dust and grime that accompanies this manufacturing operation, Speedaire continues to perform at full efficiency.**

Speedaire is Cleveland's new, powerful, fan-cooled, worm-gear speed reducer. Because it is fan-cooled it will do more work—and deliver up to *double the horsepower* of standard worm units of equal frame size, at usual motor speeds. Speedaire can be installed economically on many applications where other types have been used heretofore—giving you the advantages of a compact right-angle drive. Speedaire gives the long, trouble-free service characteristic of all Cleveland units.

Catalog 300 gives a full description of Speedaire—enables you quickly to figure proper sizes for your equipment. Send for your copy. The Cleveland Worm & Gear Company, 3265 East 80th Street, Cleveland 4, Ohio.

Affiliate: The Farval Corporation, Centralized Systems of Lubrication. In Canada: Peacock Brothers Limited.

CLEVELAND
Worm Gear
Speed Reducers

Medical

Two-tube diagnostic X-ray apparatus, North American Phillips Co. Inc., New York 17.
Chest X-ray unit, North American Philips Co. Inc., New York.

Metalworking

Large internal grinder, Bryant Chucking Grinder Co., Springfield, Vt.
Deburring machine, Globe Stamping Div., Hupp Motor Car Corp., Cleveland.
Metal distintegrator, Drafto Corp., Cochranton, Pa.
Tube end forming machine, Vaill Engineering Co., Waterbury, Conn.
Precision toolmakers lathe, Monarch Machine Tool Co., Sidney, O.
Hand screw machine, Monarch Machine Tool Co., Sidney, O.
High-speed saw, Wyzenbeck & Staff, Chicago 22.
Spinner-riveter, Plymouth Engineering Co., Plymouth, Ind.
Impact air hammer, Mead Specialties Co., Chicago.
Carbide tool grinder, Willey's Carbide Tool Co., Detroit 1.
36-inch swing lathe, Lehmann Machine Co., St. Louis.
Flexible power press, General Mfg. Co., Detroit 11.
Heavy-duty hydraulic bending press, Equipment Sales Co. Inc., Oakland 12, Calif.
Screw drum type screw machine parts rinsing and drying machine, Optimus Equipment Co., Matawan, N. J.
Crankshaper, Smith & Mills Co., Cincinnati 25.
24-inch disk grinder, Kindt-Collins Co., Cleveland 11.
Thread rolling machine, Rolled Thread Die Co., Worcester 2, Mass.
Special-purpose four-stage machine for drilling, spotfacing, counterboring and tapping, Hydraulic Machinery Inc., Dearborn, Mich.
Vertical boring machine, Giern & Anholtt Tool Co., Detroit 7.
Self-contained 500-ton forming press, Watson-Stillman Co., Roselle, N. J.
Automatic nipple machine, Landis Machine Co., Waynesboro, Pa.
All-hydraulic die casting machine, The Hydraulic Press Mfg. Co., Mt. Gilead, O.
Boring machine, Davis & Thompson Co., Milwaukee 14.
Flat lapping machine, Spitfire Tools Inc., Chicago 41.

Mining

Heavy-duty power shovel, Marion Power Shovel Co., Marion, O.
Portable crushing plant, Dixie Machinery Co., St. Louis.
Self-propelled dual crushing plant, Lippman Engineering Works, Milwaukee.
Mine gathering pump, Marlow Pumps, Ridgewood, N. J.
Car spotting hoist, Flood City Brass & Electric Co., Johnson, Pa.
Large-capacity, heavy-duty screening-grizzly feeders, Syntron Co., Homer City, Pa.
Wagon drill, Worthington Pump & Machinery Corp., Harrison, N. J.

Packaging

Three automatic packaging machines, Wright's Automatic Machinery Co., Durham, N. C.
Carton glue sealing machine, Container Equipment Corp., Newark 4, N. J.
Soaker and bottle washer, Dostal & Lowey Co., Menomonee Falls, Wis.
Solenoid operated heat sealer, Pack-Rite Machines, Milwaukee 1.
Automatic weigher, Wright's Automatic Machinery Co., Durham, N. C.
Ice cream container filler, Anderson Bros. Mfg. Co., Rockford, Ill.
Rotary unscrambling table, The Island Equipment Corp., New York 17.
Continuous heat sealer, Wrapade Machine Co. Inc., Newark 2, N. J.
Labeler, Vac Spray Machine Co., Minneapolis.
Portable bag bumper, ASCO Mfg. Co., Los Angeles 23.
Bagging scale, OK Scale Co., Buffalo 13
Tape sealing machine for lids, Package Machinery Co., Springfield, Mass.
Volumetric filler, Triangle Packaging Machinery Co., Chicago 51.
Textile wrapping machine, Package Machinery Co., Springfield, Mass.

Plastics

100-ton semiautomatic molding press, Watson-Stillman Co., Roselle, N. J.
Preheater, Airtronics Mfg. Co., Los Angeles.

Pulp and Paper

Rotary disk refiner, Sprout, Waldron & Co., Muncy, Pa.

Quarry

Pushbutton control block machine, Kent Machine Co., Cuyahoga Falls, Ohio.
Block machine with floating vibrating units, F. C. George Machine Co., Orlando, Fla.
Lever arm action block machine, Gravely Concrete Block Machinery Co., Orlando, Fla.

Restaurant

Electric slicer, American Slicing Machine Co., Chicago 11.
Automatic fryers and griddles, Walter & Correll Mfg. Co., Denver, Colo.
Electrically operated insecticide sprayers, The Sprayer Corp. of America, Chicago 40.
Frozen food cabinets, York Corp., York, Pa.

Rubber

Vulcanizer, National Rubber Machinery Co., Akron 11, O.
X-ray photometer, General Electric Co., Schenectady, N. Y.
Pin-drafting machine, Warner & Swasey, Cleveland.
Electronic seamer for thermoplastics, Union Special Machine Co., Chicago.

Testing

Bearing race tester, Physicist Research Co., Ann Arbor, Mich.

Textile

Plain jersey knitting machine, H. Brinton Co., Philadelphia 24.

Tobacco

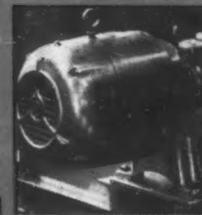
Thresher, Sprout Waldron & Co., Muncy, Pa.

Vending

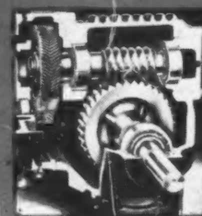
Coca Cola vending machine, F. L. Jacobs Co., Indianapolis.

Woodworking

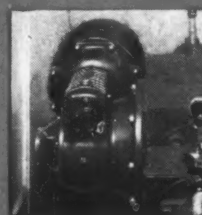
Lightweight portable 12-inch radial saw, American Saw Mill Machinery Co., Hackettstown, N. J.



the RIGHT horsepower



the RIGHT shaft speed



the RIGHT mounting

All of these . . . the explosion-proof motor, the gear-reduction unit and the flange mounting . . . all are standard Master units that easily combine into one compact, integral power drive for this double action proportioning pump. This integral construction permits many parts to be stripped away from both the power unit and the completed machine and pays off handsomely in savings in material . . . savings in space.

Probably you will not need exactly this same combination of features, but Master Gearmotors are available in any size from 100 down to 1/10 horsepower and in all cycles, phases and frequencies . . . in open, splash-proof, fan-cooled and explosion-proof types . . . with Speedrangers and Unibrakes . . . for every type mounting . . . and over a gear reduction range up to 432 to 1.

Use Master Gearmotors to increase the salability of your motor-driven products . . . improve the economy, safety and productivity of your plant equipment. They're the horsesense way to use horsepower.

THE MASTER ELECTRIC COMPANY • DAYTON 1, OHIO


Tapered Roller
TIMKEN BEARING
EQUIPPED
Production Booster
TIMKEN
MADE IN U.S.A.
TIMKEN
TAPERED ROLLER BEARINGS
THE TIMKEN ROLLER BEARING COMPANY, CANTON 6, OHIO